Study of Factors Influencing Electricity Use in Newington

Final Report

Prepared by

Institute for Sustainable Futures

For

Demand Management and Planning Project

(NSW Department of Planning)

Institute for Sustainable Futures

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***Authors*:**

Chris Riedy and Emma Partridge

Institute for Sustainable Futures

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EXECUTIVE SUMMARY

Introduction

The Demand Management and Planning Project (DMPP) is a joint venture between the NSW Department of Planning, TransGrid and Energy Australia. The DMPP's mission is to enable the cost-effective deferral or avoidance of major new electrical infrastructure works by providing accurate and reliable information on available electrical demand reduction opportunities.

One of the projects undertaken as part of the DMPP was a Photovoltaic Monitoring and Assessment Program at Newington, in western Sydney. Interval meters were installed in June 2004 to monitor electricity consumption patterns in 30 homes equipped with roof top photovoltaic (PV) panels and solar water heaters. These homes had very similar design features and characteristics. It was therefore assumed that the patterns of electricity consumption would be very similar across the 30 homes. However, when the results came in, it became apparent that the electricity consumption patterns were highly variable.

Consequently, the DMPP decided to undertake an additional study to investigate the demographic, behavioural and infrastructure-related factors responsible for the observed variation in electricity consumption patterns. The DMPP engaged the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney (UTS) to undertake the study. This report documents the study methodology and findings.

Methodology

The study used a mail survey of the 30 metered homes to collect data on the demographic, behavioural and attitudinal characteristics of the households and their installed appliances and equipment. To encourage participation, the householders were offered incentives to complete the survey, including compact fluorescent light bulbs and a WISH Gift Card, which provided the equivalent of $50 in cash to spend at participating Woolworths stores. The researchers also visited each of the homes to seek participation. A total of 15 households returned completed surveys, giving a final response rate of 50%.[1]

The DMPP provided two load profiles for each of the 30 homes – one for a particularly hot week in March 2005 (Sunday 13 March to Saturday 19 March) and one for a particularly cold week in June 2005 (Sunday 19 June to Saturday 25 June). The primary methodological challenge for the project was to find ways to explain these load profiles using the information collected in the survey.

Two main analytical approaches were employed. First, descriptive case studies were developed for each of the 15 respondent sites by visually inspecting the load profiles and explaining key features using the survey responses. Second, statistical analysis methods were used to identify relationships between a set of variables developed from the metering data and a set of variables developed from the survey data. The main statistical technique used was multiple linear regression.

[1] As a consequence of the small sample sizes, for both the metering and the survey, the numerical results from this study should not be generalised to a larger population. The sample size does not meet the requirements of *Australian Standard AS ISO 11453-2004: Statistical interpretation of data – Tests and confidence intervals relating to proportions*. Nevertheless, the findings are indicative of relationships that may exist in larger populations.

Construction details and demographics

The Newington homes were designed and constructed to be more energy efficient than a typical Sydney home. The homes involved in the study include a mix of three and four bedroom, two-storey houses, generally with northerly aspects. They are of timber framed, brick veneer construction, with two bathrooms upstairs and a WC downstairs. All of the houses were fitted with gas-boosted solar hot water systems and solar photovoltaic cells, rated at 1 kilowatt peak electricity output. The houses were also fitted with natural gas heating and cooktops. Other appliances installed at the time of construction were electric, of average efficiency. The houses have roof and wall insulation installed but no curtains in place unless fitted by the purchaser. Glazing was standard gauge glass and there were no ceiling fans installed at the time of construction.

Demographic analysis indicated that the occupants of the participating homes were not representative of the Sydney average. In general, the study sample can be characterised as including a disproportionately high number of adults of working age, males, small households, couples without children, group households, owner occupiers, households with high income and people who speak a language other than English at home. It has a disproportionately low number of young and elderly people, females, couple-families with children, lone person households, tenants and people reporting a disability.

Metering data

The DMPP provided load profiles for a particularly hot week in March 2005 and a particularly cold week in June 2005. The DMPP also provided the raw data used to develop the load profiles. From these data, several metering variables were developed to capture the main points of variation across the 30 metered households (e.g. average demand in March, peak demand in June etc). These variables were plotted and examined to gain an initial understanding of the variation in load profiles. All variables showed significant variation across the sample.

Average demand in both March and June was more than four times higher for the household with the highest electricity consumption compared to the household with the lowest consumption. Overall, average demand was higher in June than in March, although particular households consumed more in March than in June.

Despite the similarities in construction across the homes, average demand was more than four times greater in the household with the highest electricity consumption compared to that with the lowest consumption. Peak demand was more than ten times greater in the household with the highest peak demand compared to that with the lowest peak demand. Other metering variables (e.g. minimum demand and number of peaks) showed similar ranges.

Considering that the efficiency of these homes would tend to drive demand down compared to the Sydney average, and that the availability of solar water heating and natural gas heating and cooking would have a similar effect, it is reasonable to assume that homes outside Newington would demonstrate even greater variation in electricity consumption patterns. All-electric homes, in particular, would tend to have higher demand than this sample.

Site case studies

The descriptive case studies developed for the 15 participating sites were particularly useful for drawing out the key factors influencing variability in electricity consumption patterns. It quickly became evident that no single variable, or small set of variables, could easily explain the observed variation in load profiles. While most households exhibited a morning peak and a higher evening peak, each household had unique circumstances that affected the timing, size and shape of these peaks.

Nevertheless, some common themes began to emerge from the case study analysis. It was apparent that demographic characteristics alone were a poor predictor of electricity consumption patterns. While household size and structure were important, the behaviours of the household participants were more important. Large households that spent little time at home and used few major appliances commonly had lower average and peak demand than small households that had high occupancy rates and high rates of appliance use.

Behavioural factors with a particular influence on consumption patterns included occupancy patterns (which were influenced by waking and sleeping times, work patterns and whether the household included school children) and space conditioning behaviour (such as differences in temperature tolerance and timing of use of heating and cooling appliances). These factors had a major influence on the timing, size and shape of morning and evening peaks.

The cohort of appliances and equipment present in each household also had a major influence on the shape of the load profiles. In some households, the number of appliances and fixtures seemed to be a good predictor of average demand. However, more generally, the number and type of heating and cooling appliances and home entertainment equipment appeared to have the most influence on peak demand.

Households that had installed air conditioning systems tended to have sharp, distinct peaks in their March load profile, corresponding closely to the time of use of these systems. Households that used fans tended to have flatter profiles. Surprisingly, given the availability of gas heating, most of the households owned electric heaters and these were often used. The peaks generated by winter heating were often as sharp and distinct as those generated by summer air conditioning. Heating and cooling appliances created peaks outside the normal morning and evening peaks when they were used outside these hours.

Home entertainment equipment appeared to contribute strongly to the timing and shape of evening peaks in particular. The biggest peaks tended to occur when people arrived home from work or school and heating and cooling was used in conjunction with home entertainment equipment.

Statistical analysis

The statistical analysis complemented the case study analysis by searching for more formal relationships between average and peak demand and the survey responses. Linear regression was used to search for relationships between average demand and household size, the number of bedrooms and daytime occupancy rates. No convincing relationships were found. Similarly, linear regression was used to examine the relationship between peak demand and the presence of air conditioners and electric heaters. Again, no convincing relationships were found. The linear regression confirmed that no single variable could explain more than a small proportion of the observed variation in average and peak demand.

Given this finding, multiple regression analysis was used to identify the groups of survey variables that were most useful for explaining the variation in average and peak demand. Regression models were identified for average demand in March and June and peak demand in March and June.

Findings from the regression model for average demand in March were as follows:

- The factor with the most influence on average demand in March was the number of person hours of daytime occupation (between 9am and 6pm). This makes sense, as households that have members at home during the day will have higher average demand than those households in which people are away from home (and using energy elsewhere).

- There was a negative correlation between average demand in March and agreement with the statement 'I always turn off lights when they are not being used'. That is, demand decreases as people make more effort to turn off lights. This makes sense and offers some encouragement that turning off lights does have an impact on electricity use.

- There was a positive correlation between average demand in March and agreement with the statement 'I actively try to save energy around the house'. It seems strange, at first glance, that households that are actively trying to save energy have higher average demand. However, after further consideration, it makes sense that those households with the highest energy consumption (and largest bills) would be most motivated to try to save energy.

- Household income was negatively correlated with average demand in March. That is, average demand fell as income increased. This is the opposite of the relationship that is usually thought to hold between income and energy consumption. A possible explanation for this finding is that households with higher income are more able to afford efficient appliances and that this leads to lower average energy consumption. Another possibility is that households with higher income are more able to afford to eat away from home and spend time pursuing leisure and entertainment interests, which means that they spend less time at home using energy.

The findings for average demand in June, in summary, were:

- The number of electric heaters in the home and the heating time on a cold day are both positively correlated with average June demand. Heating time had the greatest influence on June demand, with a difference of 0.667 kW between those homes that do not use electric heaters and those that use heaters for the longest period of time.

- As observed in the March data, there was a positive correlation between average demand and agreement with the statement 'I actively try to save energy around the house' and a negative correlation between average demand and agreement with the statement 'I always turn off lights when they are not being used'. This indicates that these two factors are important year round, rather than just in particular seasons.

The factors influencing peak demand are notably different from those influencing average demand. In summary, the findings for March were as follows:

- The largest influence on peak demand in March was the positive correlation between peak demand and agreement with the statement 'I actively try to save energy around the house'. This relationship was also observed for average demand.

- The next largest influence was a negative correlation between peak demand and agreement with the statement "I have received information about saving energy in the past'. This may indicate that households with knowledge and awareness of the need to save energy are more likely to moderate their discretionary demand, contributing to reduced peak demand. This provides some support for the value of information and awareness campaigns.

- The number of refrigerators, reverse cycle air conditioners and high-watt lights are all positively correlated with peak demand:

  - Refrigerators, as they are always on, provide much of the baseline demand that determines how high peak demand can reach. Refrigerators have higher demand in summer periods, when temperatures are higher, so are more likely to contribute to summer peaks than winter peaks. In this study, households with three refrigerators (the highest number observed) have peak demand that is 0.872 kW higher than households with one refrigerator.

  - High-watt lights can add up to 0.389 kW to peaks.

  - The presence of a reverse cycle air conditioner adds in the order of 0.31 kW to the size of observed peaks in summer.

- There was a negative correlation between the number of fans present and the peak demand. This indicates that, relative to the rest of the sample, households with more fans are less likely to use air conditioning, and therefore have lower peak demand.

- Finally, there was a positive correlation between peak demand and the number of person hours spent at home during the day. Occupancy during the day seems to increase the size of observed peaks, perhaps because there is overlap between energy consumption associated with people working from home and consumption by other occupants returning home from work.

The findings for peak demand in June were as follows:

- Reverse cycle air conditioners (used as heating) had a very significant influence on peak winter demand. A reverse cycle air conditioner adds about 1.91 kW to peak demand (in this sample).

- Peak demand in June is also positively correlated with income. Households with higher income are more likely to be able to afford expensive air conditioners, dryers, home entertainment equipment and other appliances that contribute to peak demand.

- Finally, peak demand is positively correlated with agreement with the statement ‘I have sought information about saving energy in the past’. As with the correlations observed previously for the statement ‘I actively try to save energy around the house’, it is possible that households that have sought information about reducing their energy bills are those that have the highest demand, and therefore the most incentive to reduce demand. Alternatively, this correlation may be an artefact of the small sample size.

Conclusions

The primary objective of this study was to identify the source of large observed variations in electricity consumption patterns in 30 Newington homes with very similar constructed characteristics. The intention was not to develop statistically significant results that could be applied elsewhere in Sydney. Instead, we sought to test a theory that demographics, behaviour and variations in owner-purchased appliances and equipment have a major influence on electricity consumption patterns and peak demand. The study has emphatically confirmed the role of these factors in determining electricity consumption patterns.

Despite the similarities in construction across the homes, average demand was more than four times greater in the household with the highest electricity consumption compared to that with the lowest consumption. Peak demand was more than ten times greater in the household with the highest peak demand compared to that with the lowest peak demand. Considering that the efficiency of these homes would tend to drive demand down compared to the Sydney average, and that the availability of solar water heating and natural gas heating and cooking would have a similar effect, it is reasonable to assume that homes outside Newington would demonstrate even greater variation in electricity consumption patterns. All-electric homes, in particular, would tend to have higher demand than this sample.

Although this study used a small sample of households from a distinctive area of Sydney, the results of the case study analysis and statistical analysis are sufficient to support the theory that behaviour, habits and lifestyle have a major impact on the variation in patterns of electricity consumption. By examining a situation where the design features of the homes were relatively constant, it has been possible to draw out the importance of non-design features in determining average and peak demand.

The variables that appear to have the most value in predicting average demand are:

- Occupancy patterns (i.e. the total person hours spent at home and the person hours spent at home during the day)
- The number and efficiency of key appliances that are present, particularly air conditioners, heaters, refrigerators and home entertainment equipment
- The usage patterns for these appliances (i.e. time spent heating, cooling and using home entertainment equipment).

As peak demand is superimposed on average demand, the variables that are useful for predicting average demand are also useful for predicting peak demand. However, the number and efficiency of heating and cooling appliances and home entertainment equipment, and their usage patterns, appear to have the biggest impact on the size, shape and timing of peaks.

The descriptive case study analysis seemed to indicate that homes with air conditioners have the highest peak summer demand and homes that use a lot of electric heating have the highest peak winter demand. However, this influence did not emerge as strongly in the statistical analysis, with the exception of the strong influence of reverse cycle air conditioners on peak winter demand. Peaks can also result from the simultaneous use of home entertainment equipment, computers and cooking appliances in evening periods, even when heating and cooling does not take place.

The timing of peak demand varied across the sample. Although there was typically a morning peak and a higher evening peak, the timing depended on occupancy patterns. Further, use of heating or cooling appliances could create peaks outside of the typical times.

It would appear that there is definite scope to employ a similar methodology on other metering projects, using a larger sample to improve representation. It would be advantageous to design any future survey research in conjunction with the metering program, so that some of the methodological challenges faced during this study could be avoided. Future surveys could be designed to more closely target the variables identified as important during this study, providing a greater level of detail about occupancy patterns, heating and cooling and use of home entertainment equipment. The study could also examine factors that were not closely examined during this study, such as the influence of insulation on the timing and magnitude of peaks. The value of such a study would be in confirming the variables that influence demand across a wider sample, providing a foundation for the development of policy initiatives to target the most important variables.

Finally, it is clear from this study that policy initiatives focused on the thermal efficiency of the building envelope and the efficiency of appliances installed at the time of construction only address one of the sources of variation in average and peak demand. Household behaviour, demographic characteristics, appliances installed by occupants and attitudes are other major sources of variation in average and peak demand that need to be considered in a comprehensive policy approach. In other words, technology alone will not bring about desired reductions in average and peak electricity demand. Policies focused on awareness-raising and behaviour modification, through education, regulation and incentives, are critical to bring about desired reductions in average and peak demand.

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ABBREVIATIONS

DMPP	Demand Management and Planning Project
ISF	Institute for Sustainable Futures
kW	kilowatts
PV	Photovoltaic
SWH	Solar water heater
TCA	Testing and Certification Australia
UTS	University of Technology, Sydney

1 INTRODUCTION

The Demand Management and Planning Project (DMPP) is a joint venture between the NSW Department of Planning, TransGrid and Energy Australia. The DMPP's mission is to enable the cost-effective deferral or avoidance of major new electrical infrastructure works by providing accurate and reliable information on available electrical demand reduction opportunities.

One of the projects undertaken as part of the DMPP is a Photovoltaic Monitoring and Assessment Program at Newington, in western Sydney. Newington was the site of the Athlete's Village for the Sydney Olympic Games in 2000. It has since developed into a suburb with about 4,000 residents. Mirvac and Lend Lease are developing the site with a mix of houses and apartments that seek to incorporate principles of ecological sustainability. The houses have roof top photovoltaic (PV) panels to generate electricity and roof top solar water heaters.

In June 2004, Testing and Certification Australia (TCA) installed interval meters in 30 Newington homes. The interval meters monitored household electricity demand as part of a technical review of the impact of PV panels on demand reduction. Traditional electricity meters measure total electricity consumed and are typically read only four times per year. In contrast, interval meters provide continuous data on the electricity consumed during every half-hour period. They allow detailed analysis of the patterns of electricity consumption in a particular home.

Two separate interval meters were installed – one to measure the electricity generated by the PV panels and one to measure the electricity received or sent to the electricity grid by the home. Data on electricity consumption were collected over a period of fifteen months.

The 30 Newington homes had very similar design features and characteristics. It was therefore assumed that the patterns of electricity consumption would be very similar across the 30 homes. However, when the results came in, it became apparent that the electricity consumption patterns were highly variable. Consequently, the DMPP decided to undertake an additional study to investigate the reasons for the observed variation in electricity consumption patterns.

In October 2005, the DMPP engaged the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney (UTS) to undertake a study of the demographic, behavioural and household infrastructure-related factors influencing the measured patterns of electricity consumption in the 30 homes. Specifically, the DMPP asked ISF to undertake primary research with the households in order to explain observed patterns of consumption during a particularly hot week in March 2005 (Sunday 13 March to Saturday 19 March) and a particularly cold week in June 2005 (Sunday 19 June to Saturday 25 June). This report outlines the study methods, results and conclusions.

The report is structured as follows:

- Section 2 discusses methodological challenges for the project and the methods adopted in response to these challenges
- Section 3 gives details of the construction and fit-out of homes in Newington
- Section 4 provides additional detail on the metering data and draws out descriptive statistics to support further analysis

- Section 5 presents descriptive case study analyses for each of the participating households
- Section 6 draws on existing information and primary survey data collected during the study to define key demographic characteristics of the participating households
- Section 7 reports the results of statistical analysis to link the metering data to survey data
- Section 8 draws conclusions with respect to public policy, business practice and additional research needs.

2 METHODOLOGY

This project posed some methodological challenges. These challenges, the constraints they placed on the research, and ISF's responses are discussed in Section 2.1. Section 2.2 discusses the content of the mail survey used as the primary research tool. Section 2.3 describes the follow up work undertaken to improve the response rate. Section 2.4 summarises the data analysis process used to link the survey responses to the metered data.

2.1 Methodological challenges

There were three main challenges that needed to be addressed in designing the methodology for this study. First, the only identifying information available for each household was a postal address. Second, the volume of information required to explain patterns of household electricity consumption is large. Finally, the small sample size meant that a high response rate was critical. Each of these challenges is discussed in more detail below.

2.1.1 Limited participant details

For the 30 metered households, the DMPP was able to provide a postal address but no other details. This immediately ruled out the use of telephone or email surveys to collect data on electricity use, as no telephone numbers or email addresses were available. Contact with each household had to be initiated either by mail or by a personal visit. In this case, ISF considered that an initial contact by mail would be most respectful to the privacy of the participants and would allow for the most efficient use of research time. Personal visits could then be used to follow up with households that did not respond to the initial mail contact.

The lack of a contact name for the participants meant that an impersonal approach would be necessary, addressing mail to 'The Resident' rather than to a specific name. This raised the potential that the mail would be discarded as junk mail without being read, leading to a low response rate. The techniques employed to raise the response rate are discussed in Section 2.1.3 below.

2.1.2 Volume of data required

There are many factors that potentially influence patterns of household electricity consumption, including demographic characteristics, habits and behavioural patterns, the stock of appliances present in the home, occupancy patterns, environmental attitudes and awareness, climate and the cultural context. A questionnaire covering all of these factors could be very lengthy and detailed, which would undoubtedly reduce the response rate. However, ignoring too many of these factors would limit the explanatory power of the questionnaire responses.

Consequently, ISF sought to develop a written questionnaire that balanced time required to respond with the necessity to gather sufficient data to draw conclusions about the observed patterns of electricity consumption. Most questions could be answered by marking boxes.

2.1.3 Response rate

Given the small number of households for which metering data was available, it was clearly critical to adopt methodological strategies to maximise participation in the research by these households. Various techniques are available to maximise the quality of response to a mail survey. The techniques used in this study are described below.

1. The first strategy was to make the survey as brief and easy to complete and return as possible. While the volume and type of data required posed some constraints in this regard, ISF sought to develop the shortest, most user-friendly questionnaire that would satisfy the research needs for the project. In addition, the initial mail out included a stamped, addressed envelope in which participants could return their completed surveys. Further, ISF provided several options for potential participants. They could complete the survey and mail it back, they could call us and go through the survey over the phone or they could arrange for a face-to-face interview to go through the survey.

2. The second strategy was to provide an introductory letter from a trusted source. Although the DMPP was not well known to the participants, it was felt that the involvement of the Department of Planning would give some weight to the study. The DMPP provided a letter of introduction to mail out with the questionnaire, under the logo of the Department of Planning.

3. The third strategy was to offer psychological incentives for participation. Psychological incentives are appeals to the values or interests of the potential participant. In this case, ISF sought to appeal to both economic and environmental values. The letter of introduction and the explanatory material at the start of the survey emphasised that the research would be used to identify ways to reduce the cost and environmental impact of electricity supply in Sydney.

4. The fourth strategy was to offer direct financial incentives for participation. Financial incentives can include direct payments to participants or entry to a prize draw. In this case, given the focus on electricity consumption, ISF felt that an appropriate initial incentive would be to offer each participant an energy saving light globe as a token of appreciation. The availability of this incentive was marked on the outside of the envelope in which the survey was posted and on the survey itself.

5. A fifth strategy was to include follow up after the initial mail contact. In this case, ISF planned visits to households that did not respond to the initial survey to remind them of the survey and, where possible, to go through the survey in person.

Although a high response rate was desirable, it is important to note that even a 100% response rate would not have allowed generalisation of findings to a larger population in this case. The initial sample of 30 households for interval metering was not selected at random and the sample size was too small to generate reasonable confidence that numerical results would be more widely applicable. The sampling approach did not comply with the Australian Standard *AS ISO 11453-2004: Statistical interpretation of data – Tests and confidence intervals relating to proportions*. Given these initial constraints, the study focused on providing indicative results to test the theory that electricity consumption patterns are influenced by behaviour, demographics and infrastructure-related factors.

2.2 Survey content

The DMPP provided some initial guidance on the topics that should be covered in the questionnaire. ISF identified additional topics based on our past experience working with residential customers on energy policy issues. The final survey was divided into four parts:

- Part 1 (About your household), covering household size and structure, gender, number of bedrooms, household income, tenancy status, the presence of people with a disability and the presence of people that speak a language other than English at home

- Part 2 (Your energy use), covering electricity suppliers, billing frequency, occupancy patterns and any known alterations to the original design of the home

- Part 3 (Your appliances), covering the number and type of appliances and fittings present and usage patterns

- Part 4 (Your knowledge and opinions), covering attitudes to energy saving and environmental issues, and knowledge of the PV system and solar water heater.

Each survey was sent with a letter of introduction from the DMPP, a stamped envelope self-addressed to ISF and a participation agreement that explained the survey and sought informed consent to participate in the research. A copy of the package sent to each household is provided in Appendix 1.

2.3 Follow up work

As discussed in Section 2.1.3, ISF planned follow up visits to households that did not respond to the initial mail survey. Nine households responded to the initial mail survey within two weeks. Two ISF researchers (one male and one female) visited Newington during normal working hours on Thursday, 24 October 2005 to contact the remaining 21 households directly and deliver energy saving light globes to the nine respondents. During this visit, we talked to members of nine of the 21 households that had not responded. Two of these households elected not to participate. None of the remaining seven households were willing to work through the survey with us at the time but all accepted an additional copy of the survey with a new stamped envelope in which to return it.

The ISF researchers left a new copy of the survey with a reminder letter and a stamped envelope in the letterboxes of the 12 households that did not answer the door. A copy of the reminder letter is provided in Appendix 2. It established a due date for the surveys of Wednesday 30 November 2005.

By Thursday, 1 December 2005, no additional survey responses had been received. After consultation with the DMPP, and given the need for a higher response rate, the project team decided to offer an additional financial incentive to participants. All households that had not returned a survey by Friday 1 December 2005 were sent a reminder letter, offering a $50 WISH Gift Card[2] to those households that returned a completed survey by Wednesday 14 December 2005. A copy of the letter is provided in Appendix 3. A stamp was affixed to each

[2] The WISH Gift Card is a product offered by Woolworths that can be used as a substitute for cash at participating stores, including Woolworths. As there is a large Woolworths at the Newington Marketplace, adjacent to the study site, it was felt that this incentive would be attractive to a large proportion of the potential participants. Additional information about the WISH Gift Card scheme is available from www.wishgiftcard.com.au.

envelope, advertising the availability of the $50 WISH Gift Card, to prevent people from immediately discarding the letter as junk mail. For ethical reasons, a $50 WISH Gift Card was also delivered to the nine initial respondents.

This offer generated an additional six survey responses, bringing the total to 15. A summary of the overall response rate is provided in Table 1. Exactly 50% of the households contacted returned a completed survey.

Response Type	Number of Responses	Response Rate (%)
Initial mail survey	9	30
Responded to second offer	6	20
Refusal during site visit	2	6.7
Response rate (completed surveys)	***15***	***50***
Response rate (including refusals)	***17***	***56.7***

Table 1: Summary of response rate.

2.4 Data analysis

The DMPP provided electricity load profiles for the participating households, as well as the raw data used to generate these load profiles. The primary analytical challenge for this project was to find a way to link the complex patterns of electricity consumption evident in the metering data to demographic characteristics and practices identified using surveys. ISF used three main analytical approaches to identify links between the metering data and the survey data: case study development, linear regression and multiple linear regression.

2.4.1 Case study development

Given the small sample size for the study and the consequent lack of statistical significance, we considered that there was value in undertaking descriptive analysis of the data, in addition to statistical analysis. From visual inspection of load graphs, we identified distinctive characteristics of each household and sought explanations for these characteristics in the survey data. This allowed closer examination of the timing of peaks and how they coincided with stated behaviour from the surveys. The case studies developed in this way are discussed in Section 5.

2.4.2 Linear regression

Linear regression is a statistical method that identifies a linear relationship between two variables. We used linear regression to test some initial theories about the reasons for variation in the metering variables. The results are discussed in Section 7.2. An explanation of the linear regression technique, including an example, is provided in Appendix 4.

2.4.3 Multiple linear regression

Multiple linear regression is a statistical method for identifying linear relationships between a dependent variable and a set of independent, explanatory variables. For this project, we wanted to see if the information from the survey helped to explain the variation in the metered electricity consumption patterns. We therefore developed a set of metering variables to capture the variation in the electricity consumption patterns and a matching set of survey variables to capture the variation in survey responses. We used multiple linear regression to explore the relationship between the metering variables and the survey variables. A detailed explanation of this process, with examples, is provided in Appendix 4. The results are discussed in Section 7.3.

3 CONSTRUCTION DETAILS

The 30 homes involved in this study are part of the Newington Village development, constructed by Mirvac and Lend Lease. Newington is a medium-density residential village, comprising a mix of three and four bedroom family homes, courtyard homes, townhouses and apartments. Mirvac provided the following construction specifications for the 30 homes involved in the study:

- A mix of three and four bedroom, two-storey houses, generally with northerly aspects
- Houses are timber framed, brick veneer, with concrete tiles
- Standard tile, carpet, stone and other interior finishes
- Similar construction dates
- Two bathrooms upstairs and a WC downstairs
- All houses fitted with a gas-boosted solar hot water system
- All houses fitted with solar photovoltaic cells, rated at 1 kilowatt peak electricity output
- Natural gas heating and cooktop installed
- Oven and other appliances are electric, and are of average energy efficiency
- Roof and wall insulation is installed but no curtains are in place unless fitted by purchaser
- Glazing is standard gauge glass
- No ceiling fans.

The specifications above draw attention to several aspects of the Newington homes that differentiate them from typical Sydney homes. First, the northerly aspect and use of roof and wall insulation is likely to reduce overall space conditioning (heating and cooling) loads compared to the Sydney average. Second, the presence of a gas-boosted solar hot water system will reduce the demand for electricity and gas to heat water. Third, the use of natural gas for heating and cooking differentiates these homes from the large proportion of all-electric homes in Sydney. These differences are grounds for caution when extrapolating any results from this study across Sydney as a whole.

The specifications also draw attention to some points of differentiation within the homes, which may explain some of the observed differences in the metering data. First, it would be reasonable to expect the four bedroom homes to require more heating and cooling than the three bedroom homes. Second, homes that have made modifications, such as installing curtains, ceiling fans or air conditioning systems, will have energy consumption patterns that differ from the sample average. Survey questions were included to test for these points of differentiation.

4 METERING DATA

The DMPP provided interval meter data for two periods in 2005:

- 13 March to 19 March 2005
- 19 June to 25 June 2005

Section 4.1 provides a summary of the weather conditions prevailing during these two periods, as weather conditions are an important factor in determining use of space heating and cooling, which in turn influences energy use. Section 4.2 describes the metering data available for each week and provides examples of load graphs generated from these data. Section 4.3 discusses metering variables derived from the metering data for each site.

In the discussion below, and in the remainder of this report, we refer to the metered homes by number, from Site 1 to Site 30.

4.1 Weather conditions

The week of 13 to 19 March 2005 was relatively hot, particularly at the start of the week. Table 2 summarises weather conditions during this period, based on observations at Sydney and Penrith. Newington is approximately midway between Sydney and Penrith. For the first four days of the week, the minimum and maximum temperatures at both sites were generally above average for March. The minimum temperature at Sydney on Wednesday 16 March and the maximum temperature at Penrith on Tuesday 15 March were the highest for March at those sites. Conditions returned to more average levels later in the week, due to cloudy conditions and rainfall.

Date	Day	Min Temp (°C)		Max Temp (°C)		Rainfall (mm)		Hours of sun
		Sydney	Penrith	Sydney	Penrith	Sydney	Penrith	
Mar 13	Sun	19.2	16.6	28.8	31.6	0	0	11.4
Mar 14	Mon	19.1	15.9	27.6	31.7	0	0	11.1
Mar 15	Tue	20.5	17.3	28.4	33.5	0	0	11.1
Mar 16	Wed	20.9	18.9	24.3	29.1	0	0	2.4
Mar 17	Thu	16.9	16.1	19.1	17.9	3.0	14.6	0.0
Mar 18	Fri	16.4	14.8	21.3	18.9	22.6	8	0.0
Mar 19	Sat	16.1	15.3	23.4	22.9	2.6	1.6	7.7

Table 2: Weather conditions during the week of 13 to 19 March 2005.

The week of 19 to 25 June 2005 was relatively cold. Table 3 summarises weather conditions during this period, based on observations at Sydney and Penrith. The minimum and maximum temperatures on Thursday 23 June, for both sites, were the lowest for the month of June, although not the lowest for the year. Temperatures were generally below the monthly average on Wednesday, Thursday and Friday.

Based on the weather conditions for the two weeks considered, it would be reasonable to expect those households with space cooling equipment to make use of it during the week of 13 to 19 March and those with space heating equipment to make use of it during the week of 19 to 25 June.

Date	Day	Min Temp (°C)		Max Temp (°C)		Rainfall (mm)		Hours of sun
		Sydney	Penrith	Sydney	Penrith	Sydney	Penrith	
Jun 19	Sun	10.1	6.9	19.2	19.6	0	0.6	4.7
Jun 20	Mon	12.1	6.4	20.5	19.9	0	0	9.0
Jun 21	Tue	11.5	7.2	17.8	18.8	0	0	7.8
Jun 22	Wed	10.7	6.6	17.0	17.3	0	0	7.2
Jun 23	Thu	6.6	0.9	15.6	13.8	0	0	3.2
Jun 24	Fri	9.5	5.7	17.9	18.9	7.6	2.2	1.6
Jun 25	Sat	10.5	10.5	16.7	17.9	16.0	2.2	2.6

Table 3: Weather conditions during the week of 19 to 25 June 2005.

4.2 Electricity meter output

TCA installed two interval meters at each site. These meters measure the quantity of electricity, in watt-hours, moving past a particular point during a 30-minute interval. The first meter measured both the electricity provided by the grid and the electricity sent back to the grid. The second meter measured the electricity generated by the PV panels installed on the roof of each home.

For this project, it is electricity demand that is of primary interest, rather than the total amount of electricity consumed. Electricity demand, measured in watts (or kilowatts, kW), is the instantaneous amount of electricity required at any point in time. Electricity demand determines the size of the electricity grid, as the grid must be sized so that it can deliver the peak demand. Electricity consumption is related to electricity demand as follows:

Consumption (watt-hours) = Demand (watts) x consumption period (hours)
(1)

For each metering interval, the consumption period was 30 minutes, or 0.5 hours. Thus:

Demand (watts) = 2 x Consumption (watt-hours)
(2)

The metering data provided by TCA comprised demand data for each site, in watts and kilowatts, on a half hourly basis.

The DMPP calculated the household demand in each half-hourly period according to the following equation:

Household demand (kW) = Import from grid (kW) – export to grid (kW) + PV output
(3)

That is, the actual electricity demanded by the household was equal to the demand supplied by the grid plus the demand supplied by the PV panel minus any electricity exported from the household back to the grid. The DMPP provided graphs of household demand for each site over each of the two weeks considered. These graphs are known as load profiles or energy curves. The load profiles for the fifteen sites that responded to the survey are provided in Section 5.

The DMPP also provided the raw data used to generate the load profiles. This allowed ISF to develop summary statistics to support further analysis. This process is described in more detail in Section 4.3.

4.3 Metering variables

As discussed in Section 2.4, the key analytical challenge for this project was to link the complex patterns of electricity consumption evident in the load profiles to demographic characteristics and practices identified using surveys. To aid the analysis, a set of metering variables was developed to numerically capture the main features of each load profile. The following variables were calculated for each site, for both the March and June periods:

- Average half-hourly demand
- Peak (maximum) demand for the week
- Minimum demand for the week
- The demand range (difference between the peak demand and the minimum demand)
- The ratio of the peak demand to the average demand
- The number of half-hourly intervals in which demand was more than double average demand
- The number of half-hourly intervals in which demand was more than four times average demand.

These variables describe the shape of each load profile in sufficient detail to support further analysis in conjunction with the survey data. Each variable is discussed in more detail in the sections below. The full set of variables for the fifteen participating households is provided in Appendix 5.

4.3.1 Average household demand

Figure 1 plots average household demand for each site, in March and June. To aid interpretation, the sites have been plotted in order of ascending demand, based on the average demand in June. The average demand across all sites and the average demand for survey respondents are also shown.

Several conclusions can be drawn from these data. First, average demand across all sites is higher in the cold June period than in the hot March period. Second, average June demand at some sites is very much higher than March demand. Third, two sites have very low June demand – much lower than their March consumption. It is possible that these sites were unoccupied during the period considered. Fourth, despite the similarities in design and construction of the houses, the average energy demand varies dramatically across the sample. Average demand was as low as 0.12 kW for one household in March and as high as 0.84 kW for one household in June. Section 7 will attempt to explain these observations with reference to the survey data.

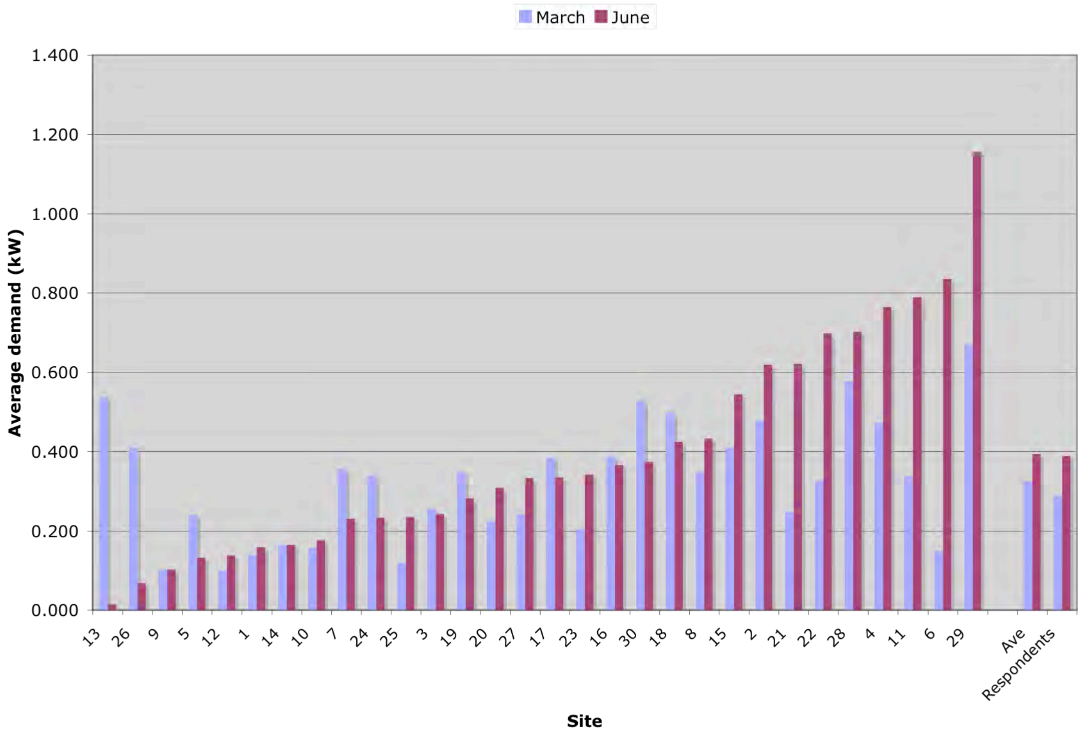


Figure 1: Average household demand for each site, ordered according to June demand.

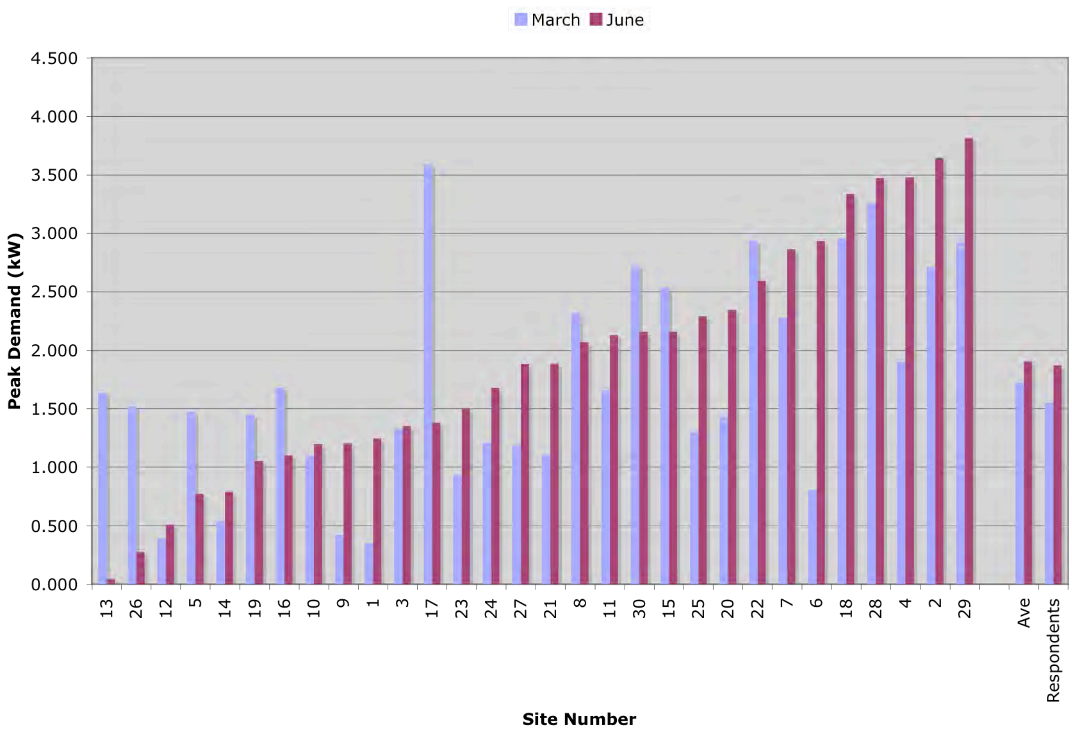


Figure 2: Peak household demand for each site, ordered according to June demand.

4.3.2 Peak demand

Figure 2 plots peak household demand for each site, in March and June. Again, to aid interpretation, the sites have been plotted in order of ascending demand, based on the peak demand in June. The conclusions that can be drawn from this graph are similar to those that can be drawn from the graph of average demand. Peak demand is generally higher in June than in March (in some cases much higher), although there are several exceptions, where peak demand is higher in March than in June. As with average demand, the results for peak demand are very diverse, ranging from a low of 0.28 kW in June to a high of 3.59 kW in March. Again, Section 7 will attempt to explain these observations with reference to the survey data.

4.3.3 Minimum demand

Figure 3 plots minimum demand, ordered according to June demand. The main observation of interest here is that minimum demand tends to be higher in March than in June, which is the reverse of the situation observed for average and peak demand. Minimum demand is likely to occur when the house is unoccupied or the occupants are asleep and will comprise passive electricity demand from refrigerators and appliances drawing standby power. It is likely that the higher minimum demand in March can be attributed to refrigerators, which need to work harder to maintain a temperature in the hotter months.

4.3.4 Demand range

Figure 4 plots the range of demand (the difference between the minimum and peak demand), ordered according to June demand. On average, the demand range is higher in June than in March. This graph adds little that was not evident from the peak demand graph in Figure 2.

4.3.5 Ratio of peak demand to average demand

Figure 5 plots the ratio of peak demand to average demand for each household. On average, this ratio is slightly higher in June than in March. Some very large peaks, as much as 12 times the average demand, are evident for some households. Some households also have much higher peaks in one period than another.

4.3.6 Number of peaks

Figure 6 plots the number of half-hourly intervals in which demand was more than four times the average household demand, for March and June data. This plot gives an approximate measure of the total peak time for each household. On average, there was more peak time in June than in March. However, ten of the thirty homes did not record any peak demand that exceeded four times the average demand in June. Similarly, six homes did not record any such peak demand in March. These observations may reflect the prevalence and use of electric heating and cooling systems across the households.

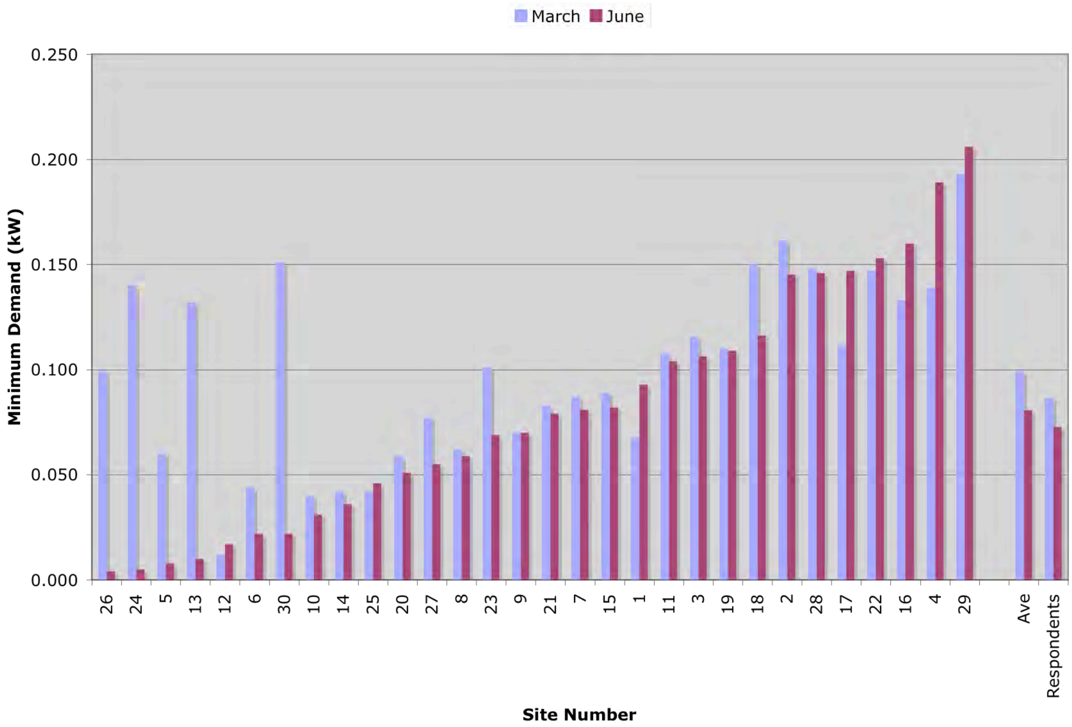


Figure 3: Minimum household demand for each site, ordered according to June demand.

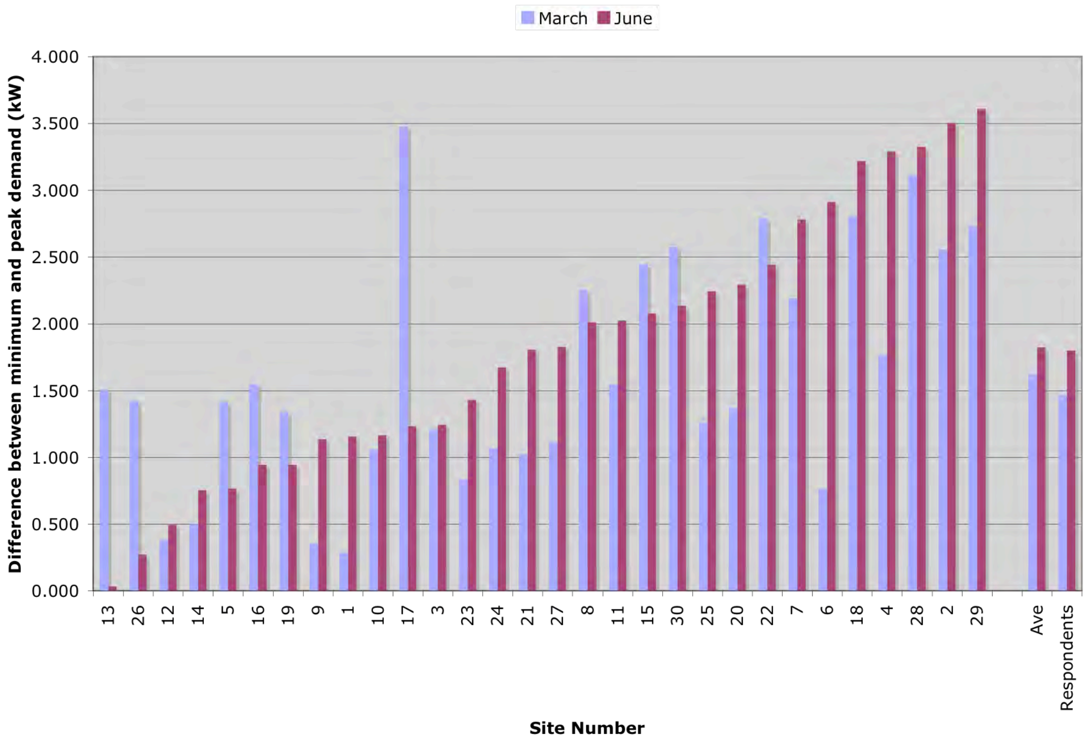


Figure 4: Range of demand for each site, ordered according to June demand.

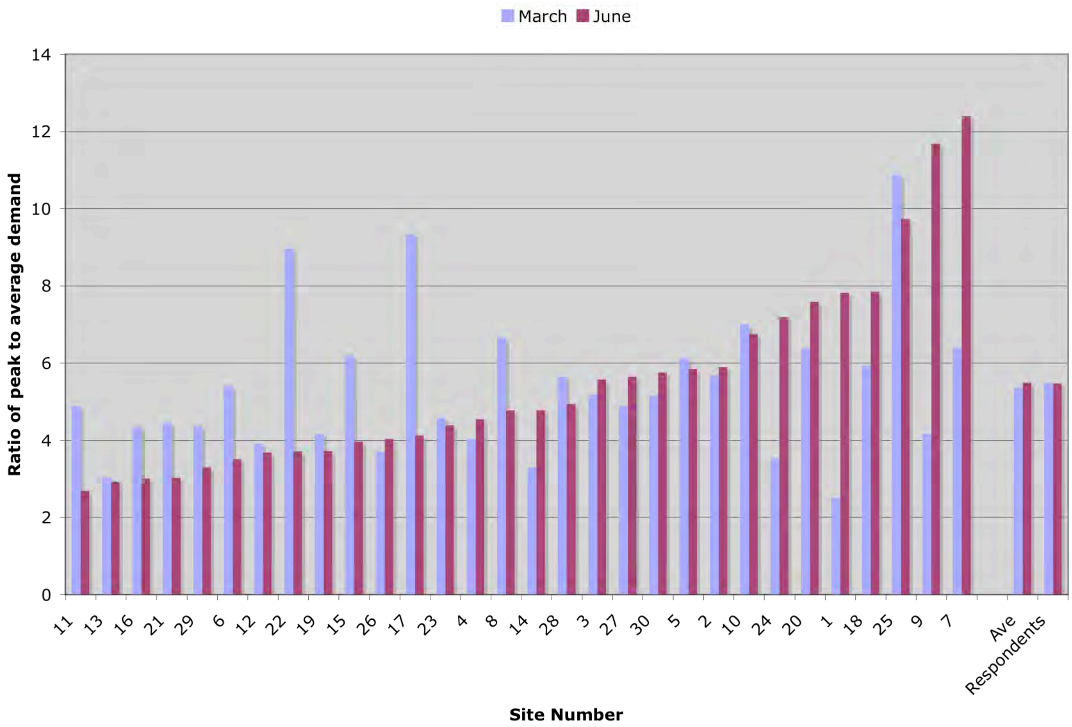


Figure 5: Ratio of peak demand to average demand, ordered according to June data.

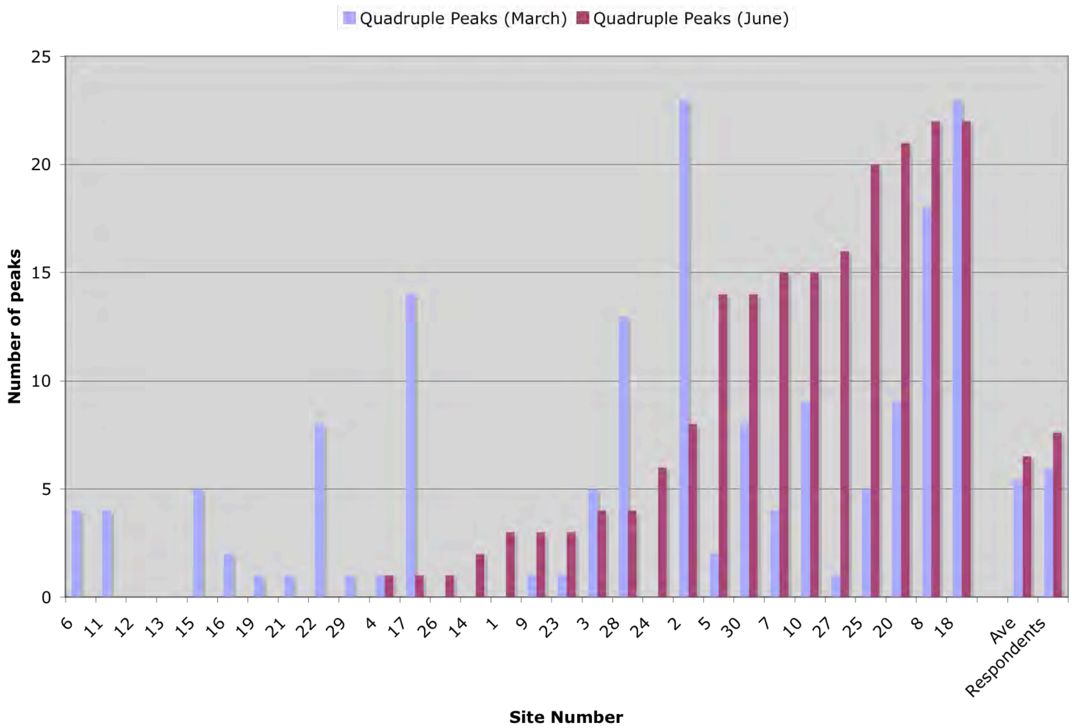


Figure 6: Number of half hourly intervals in which demand was more than four times average demand, ordered according to June data.

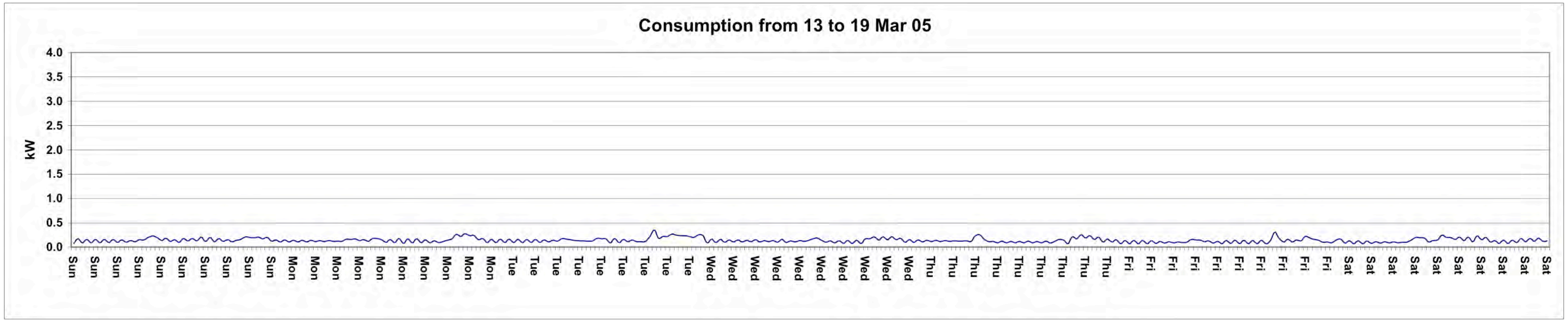
5 SITE CASE STUDIES

Given the small sample size, it is possible to examine each of the respondent sites on a case-by-case basis to identify the specific factors influencing their load profiles. This descriptive approach is valuable for drawing out the specific demographic, behavioural and infrastructure-related differences that contribute to the observed variation in load profiles. Case studies for each site are presented below. The load profiles referred to in each case study are plotted over a period from Sunday morning (starting from midnight) to Saturday night (ending at midnight). All load profiles are plotted on the same scale to give an accurate indication of the difference in demand across sites. The complete set of survey responses for the fifteen sites is provided in Appendix 6.

5.1.1 Site 1

Figure 7 shows the load profiles for Site 1. Site 1 is characterised by relatively low average demand (the second lowest of the respondent sites) and a remarkably flat load profile. There is only one significant peak, towards the end of the June period. There are several factors that explain the low average demand. Site 1 is a lone-person household with one of the highest numbers of low-watt light bulbs installed, a single electric heater (which is never used), a single standard television, portable cooling appliances, no dryer and a relatively low number of appliances and fixtures overall. The occupant is usually away during the day and their peak consumption periods tend to fall between 6am to 8am and 6pm to 10pm, corresponding with use of the kitchen, bathroom and home entertainment equipment.

The one major peak evident in the winter load profile occurred on a Saturday afternoon between 3pm and 6pm. While the survey data does not provide a specific explanation for this peak, we can speculate from data provided and the size and timing of the peak that it might have involved use of the electric oven to cook a meal or use of the vacuum cleaner to clean the house.



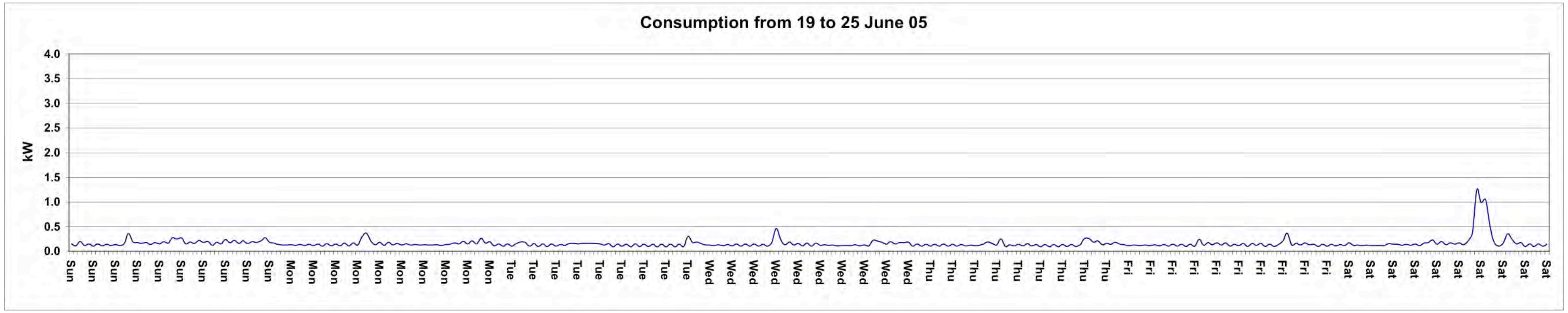


Figure 7: Load profiles for Site 1.

5.1.2 Site 4

Figure 8 shows the load profiles for Site 4. Site 4 has one of the highest levels of average demand across all sites, with numerous peaks, which are often sustained for several hours. Site 4 has four occupants – a couple with two children under the age of three. The entire family is usually home on Tuesdays and Thursdays but none are home on the other weekdays. The large household size and time spent at home during the day partially explain the high average demand. Further, peak consumption tends to occur on the days when the family is home, with lower consumption on Tuesdays and Thursdays.

Space conditioning appears to be particularly important to this household, perhaps to maintain an acceptable temperature for the young children. The household has a heat lamp in the bathroom (the only one reported in the study), one fan heater, three oil heaters, a portable fan and ducted reverse-cycle air conditioning. These heating and cooling appliances are heavily used. Air conditioning is used during the day in summer, while a fan is often left on overnight. Heating is left on overnight in winter. This behaviour helps to explain the high average demand.

The family has the highest number of appliances and fixtures of all the respondents. These include two standard televisions, a plasma screen television, two DVD players, two VCR players, two stereos, a home theatre system, two computers and three exhaust fans. The home entertainment equipment is mainly used between 7am and 8am and 5pm and 9pm, while the computer is left on all day. The microwave and electric oven are used daily. This behaviour, and the occupancy during the day, helps to explain the relatively large number of sustained peaks.

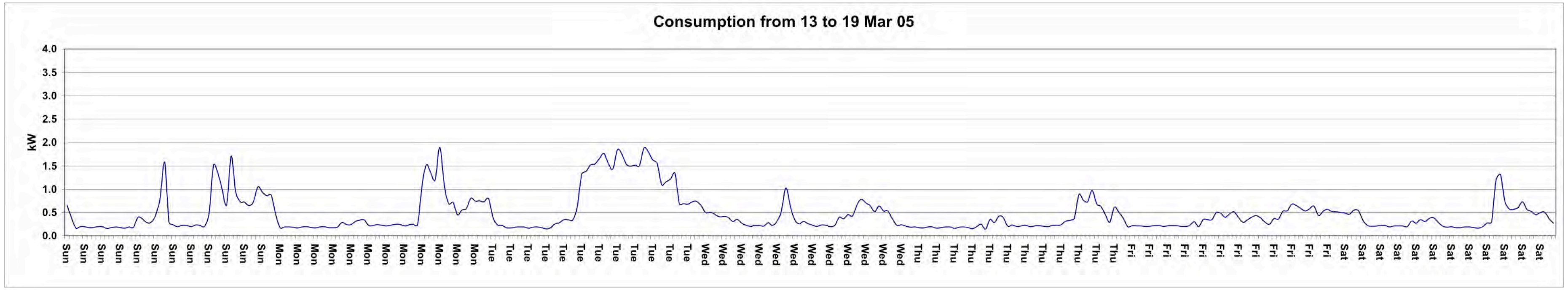
5.1.3 Site 6

Figure 9 shows the load profiles for Site 6. This site is characterised by a low level of minimum demand with unusually regular peaks. The peaks are much higher in winter than in summer.

Site 6 is occupied by a couple in their late fifties that appear to have very regular habits. They are away from home between 8am and 5pm every day but are home the rest of the time. They get up at 6am and go to bed at 10.30pm. The observed peaks in the load profiles correspond closely to the periods when the occupants are home but not asleep, from 6am to 8am and from 5pm to 10.30 pm. The morning peak is smaller and shorter in duration than the evening peak.

The couple owns a relatively small number of appliances with standby consumption and only one average-sized fridge, so demand when they are away or asleep is relatively low.

The difference in the winter and summer load profiles can be explained by a differing emphasis on heating and cooling. The occupants have one portable fan, but they use it rarely. By contrast, they have four heaters and tend to use these quite regularly in winter between 5pm and bedtime. This explains the higher winter peaks during this period.



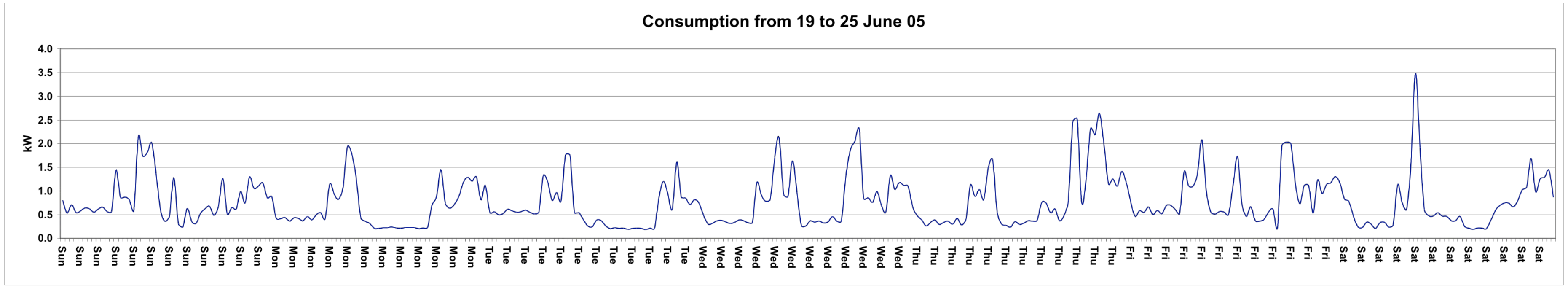
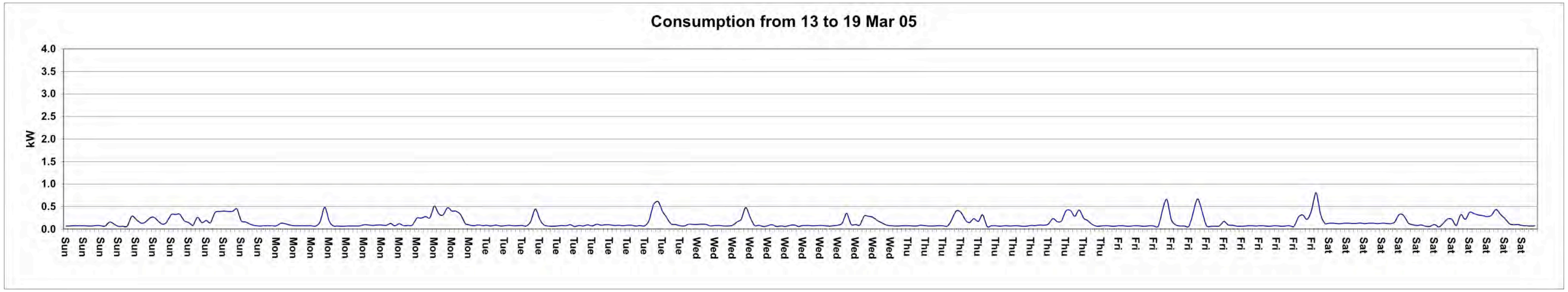


Figure 8: Load profiles for Site 4.



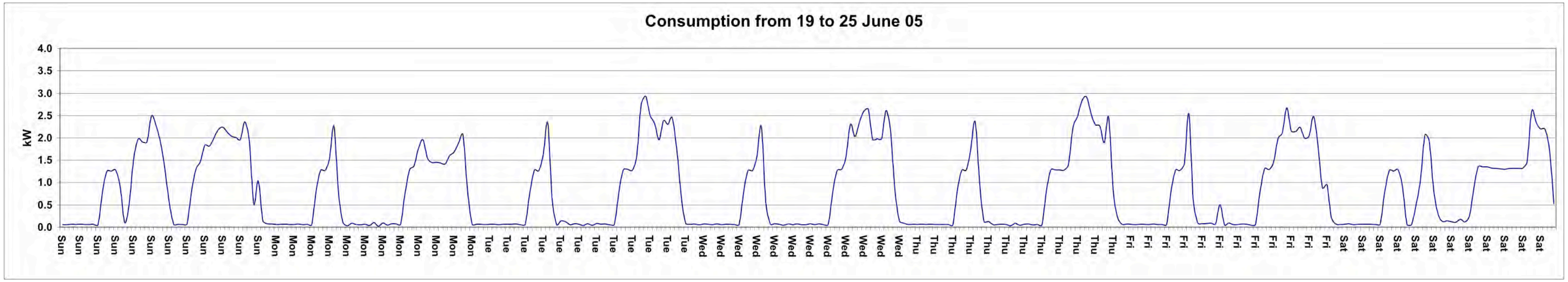


Figure 9: Load profiles for Site 6.

5.1.4 Site 8

Figure 10 shows the load profiles for Site 8. Site 8 has a relatively low level of minimum demand with relatively high peaks. The peaks are more regular in winter than in summer.

Site 8 is occupied by a lone, 40-year old female. The occupant has relatively few appliances and fixtures and is away from home on weekdays between 8am and 7pm. This is the period when consumption is typically low in the load profile.

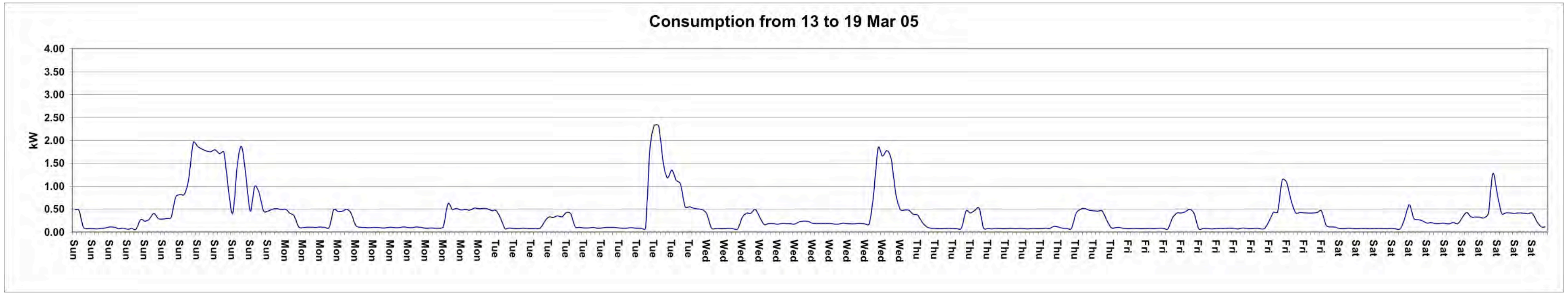
The occupant has two reverse cycle air conditioners, which are used between 7pm and 11pm on very hot days, cold days and sometimes on weekend mornings in winter. The major summer and winter peaks on the load profiles appear to correspond to times when the air conditioner was used. This site demonstrates the major contribution that air conditioning can make to peak demand. Cooking and use of home entertainment equipment also contribute to the nightly peak around 7pm to 8pm.

5.1.5 Site 10

Figure 11 shows the load profiles for Site 10. Site 10 has relatively low minimum demand and average demand, and relatively small peaks, up to 1.2 kW. Site 10 is occupied by a couple and an eight-year old child. The child attends school during the day and the home is unoccupied during school hours, except on Friday when one adult is home. The child and one parent are away from home between 3pm and 6pm on Tuesdays and Thursdays. Otherwise, all occupants are home during this period. This occupation pattern partially explains the observed load profiles. The evening peaks tend to start later on Tuesdays and Thursdays.

The household has three portable fans and a portable air conditioner. The air conditioner is used between 5pm and 10pm on very hot days, but usually only for one or two hours. The sharp peaks on the summer load profile, between 0.8 and 1 kW, are likely caused by the air conditioner. The fans are used overnight in summer, which gives a higher minimum demand on the load profile.

The household also has two oil heaters, which are used between 6pm and 11pm in winter. The heaters likely cause the observed winter peaks, of 1 to 1.2 kW. The household also has a flat screen television and home theatre system, which contribute to peaks between 5.30am and 8am, and between 6pm and 11pm.



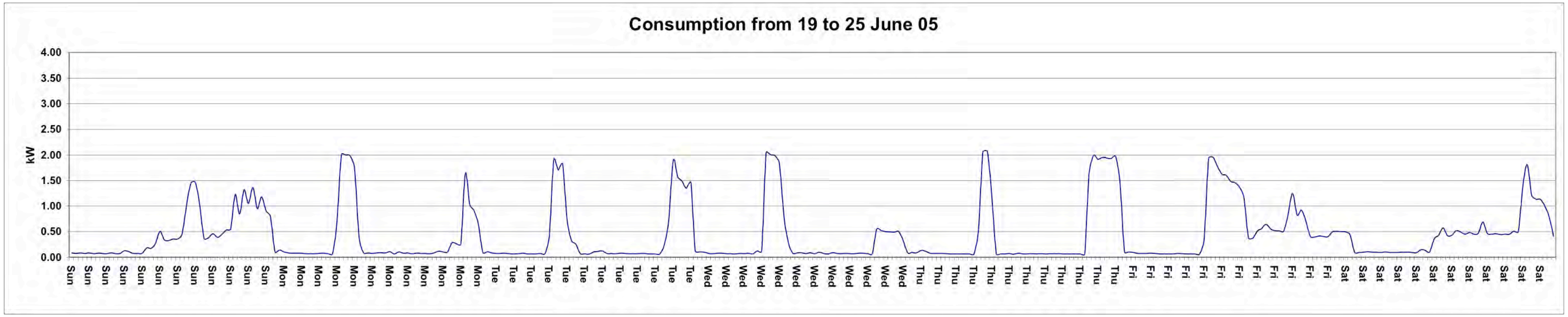


Figure 10: Load profiles for Site 8.

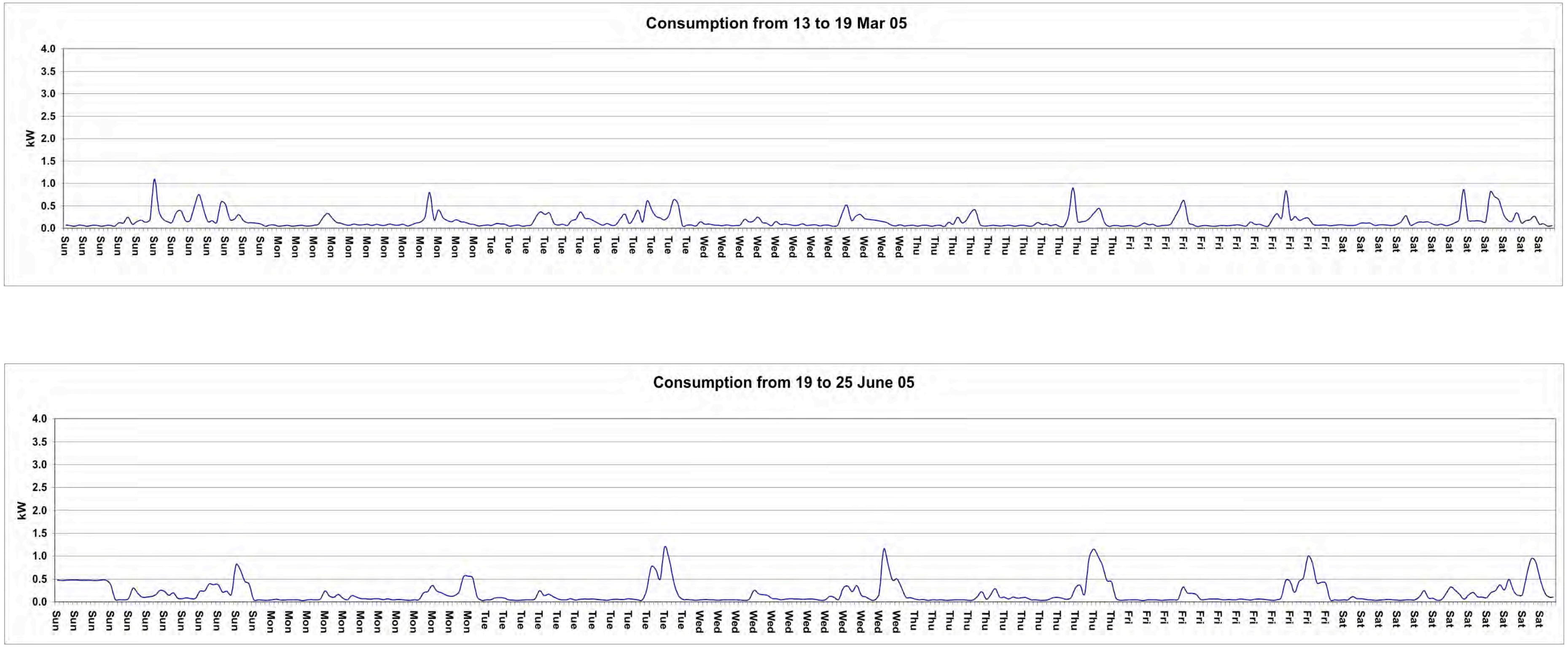


Figure 11: Load profiles for Site 10.

5.1.6 Site 11

Figure 12 shows the load profiles for Site 11. It should be noted that data for Site 11 has been estimated by using results from the PV meter at the adjacent site, as the PV meter at Site 11 is defective. Site 11 has a relatively high level of minimum and average demand, particularly in winter. However, peaks are around the average, giving the load profiles a flatter shape overall than is typical. Site 11 is occupied by three adults – a male and female in their fifties and a male in their early twenties. The occupancy patterns during the day (on weekdays) are complex, which contributes to the complex shape of the load profile. There is usually someone home during the day, but sometimes two people are home and sometimes nobody is home.

The household has three portable fans and one portable air conditioner. The fans are used all day on very hot days (when people are home), while the air conditioner is used from 7pm on very hot days. The fan use during the day may help to explain the relatively high minimum and average demand. The spikes above 1 kW in the summer load profile may be linked to air conditioner use.

The household also has three oil heaters, which are used between 6pm and 11pm on very cold days and sometimes left on overnight. The plateaus in the winter load profile appear to correspond to periods when heaters were left on overnight.

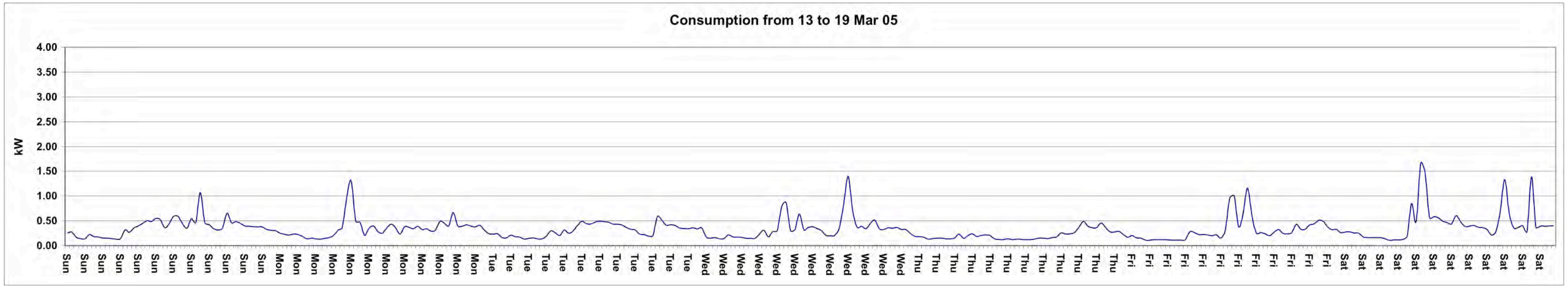
5.1.7 Site 14

Figure 13 gives the load profiles for Site 14. Site 14 has the lowest peak demand of all the respondent households, in both March and June. Its average demand is also low, although not the lowest. The load profiles include some repeating patterns on weekdays, indicating habitual behaviour patterns. Peaks are frequent, but not large.

The low average and peak demand for Site 14 is surprising, as four people occupy the household. The household structure is unusual, comprising three adults in their early fifties (two females and one male) and a 15-year old boy. The home has the most high-watt lights in the sample and one of the highest numbers of appliances and fixtures, which are factors that would tend to increase demand.

The low average and peak demand appears to be linked to the lack of air conditioning, the lack of a clothes dryer and the choice not to use electric heating. The household owns five portable fans, which are used between 6pm and 1am on very hot days. Peak summer demand tends to coincide with this period but the peaks are much lower than those that would result from air conditioning use. The household also owns one fan heater and two oil heaters but does not use these.

Occupancy also helps to explain the load profile. One adult is home during the day, but tends to use relatively low levels of electricity during this time, with occasional peaks. Demand increases (and often peaks) around 3.30pm to 4.30pm when the 15-year old boy arrives home from school. Demand remains high in the evening when the other household members arrive home.



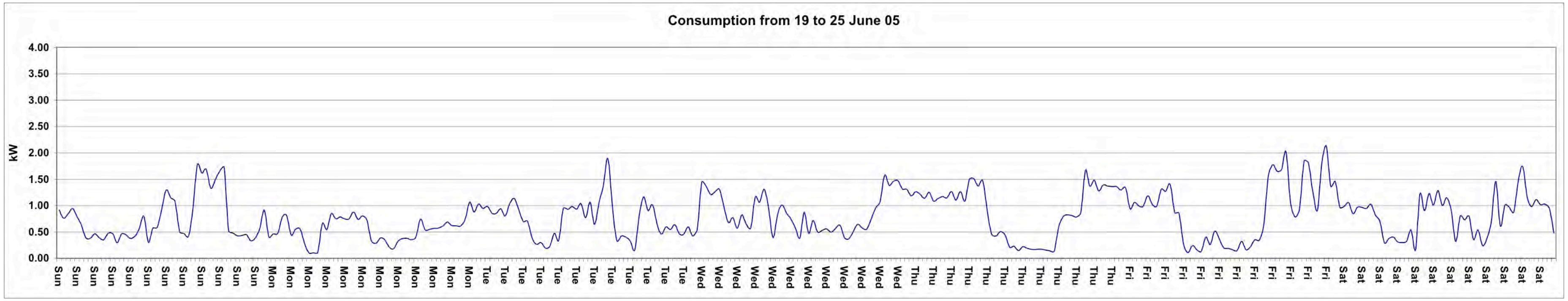
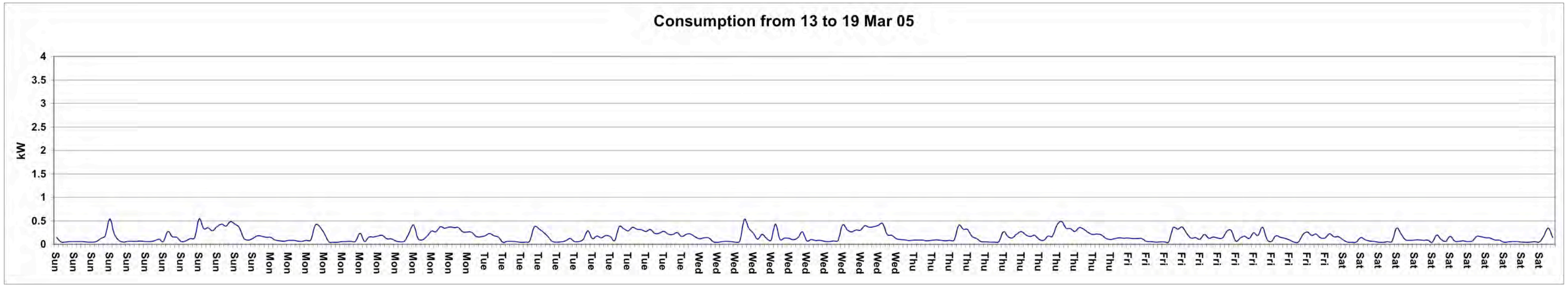


Figure 12: Load profiles for Site 11.



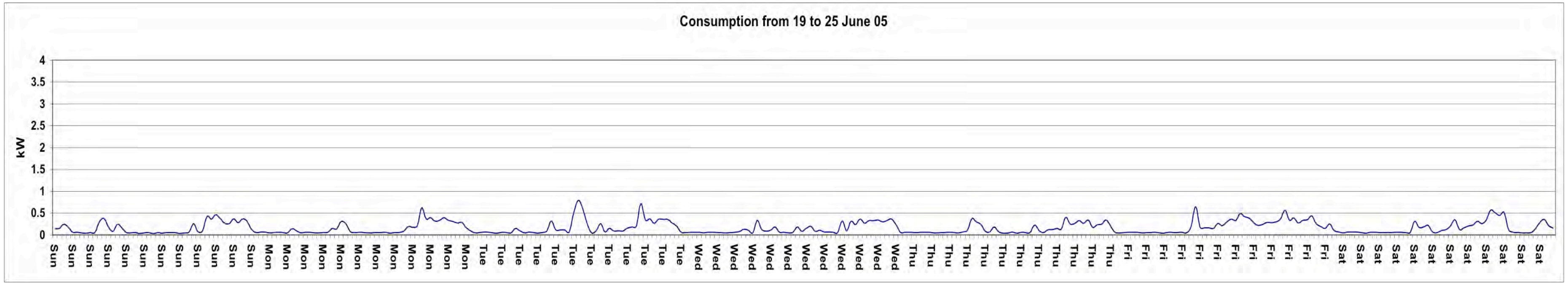


Figure 13: Load profiles for Site 14.

5.1.8 Site 17

Figure 14 gives the load profiles for Site 17. Site 17 has a relatively flat load profile, interrupted by two very large peaks in summer and occasional smaller peaks in summer and winter. This site has the highest summer peak by a considerable margin, but a relatively low winter peak. It also has high levels of minimum demand in both summer and winter. Average demand is higher than the sample average in March and lower in June.

A male and female, aged 38 and 43 respectively, occupy Site 17. Given that this is a two-person household, the large peaks and high levels of minimum demand are initially surprising. However, the survey data provides clear explanations for these observations. The large summer peaks result from the use of a ducted air conditioning system. According to the survey response, the occupants use the air conditioning during the day if the temperature is above 32°C. The two large summer peaks occurred on the Sunday morning and Tuesday afternoon, when temperatures were around 32°C (see Table 2). The lack of large winter peaks is explained by the absence of any electric heating.

The high level of minimum demand can be explained by the presence of the highest number of halogen lights, three refrigerators, three televisions and one of the highest number of appliances and fixtures overall. One of the occupants is home during the day and uses a computer all day. Small peaks occur in the evening when the other occupant comes home.

5.1.9 Site 18

Figure 15 gives the load profiles for Site 18. Site 18 has a relatively high level of average demand, with high, distinct peaks in both summer and winter. Minimum demand is also high. A male and female, aged 67 and 65 respectively, occupy Site 18. According to the survey response, they are home all day, every day.

The high levels of minimum demand for this household are linked to the constant occupancy and the presence of two refrigerators and three televisions (including one flat screen television). The high, distinct peaks are due to the use of a ducted, reverse cycle air conditioning system. The occupants report that they only use the air conditioner for short bursts in summer and winter to maintain a preferred temperature. This behaviour is clearly evident in the load profile, with sharp peaks up to 3 kW in summer and 3.5 kW in winter.

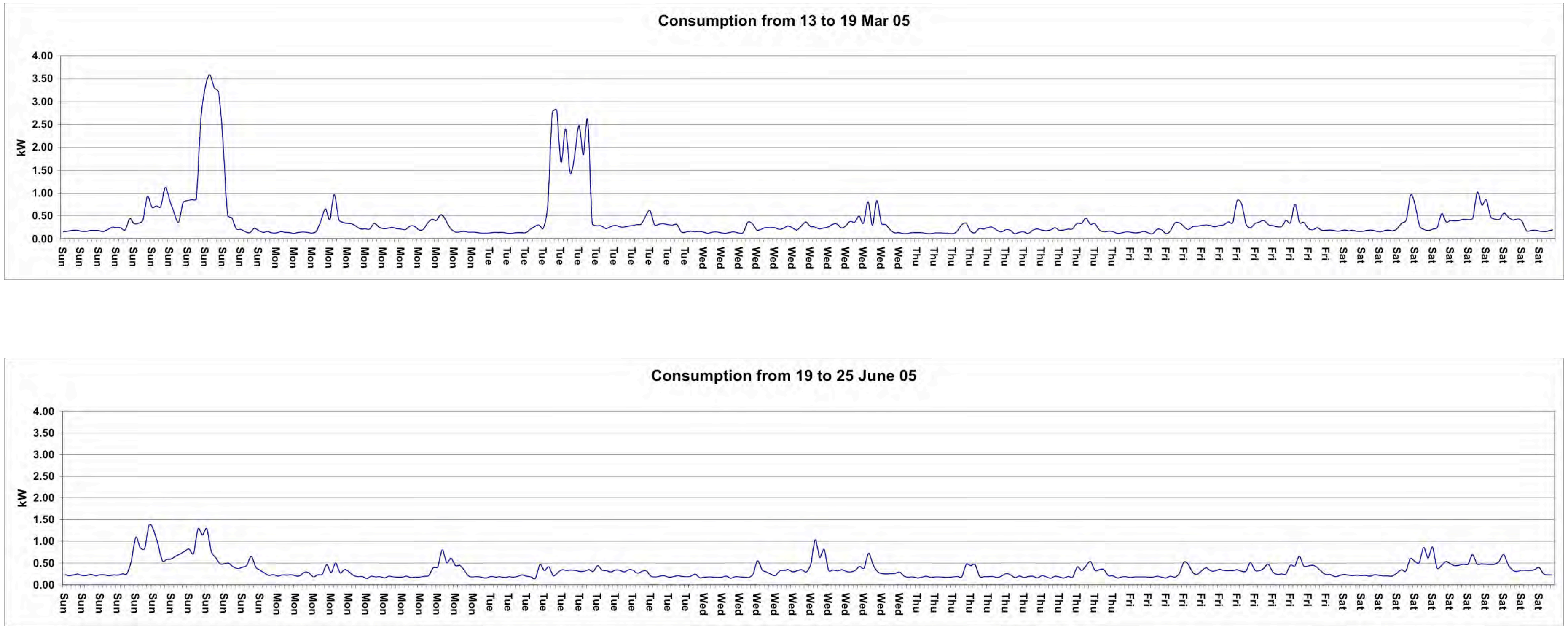
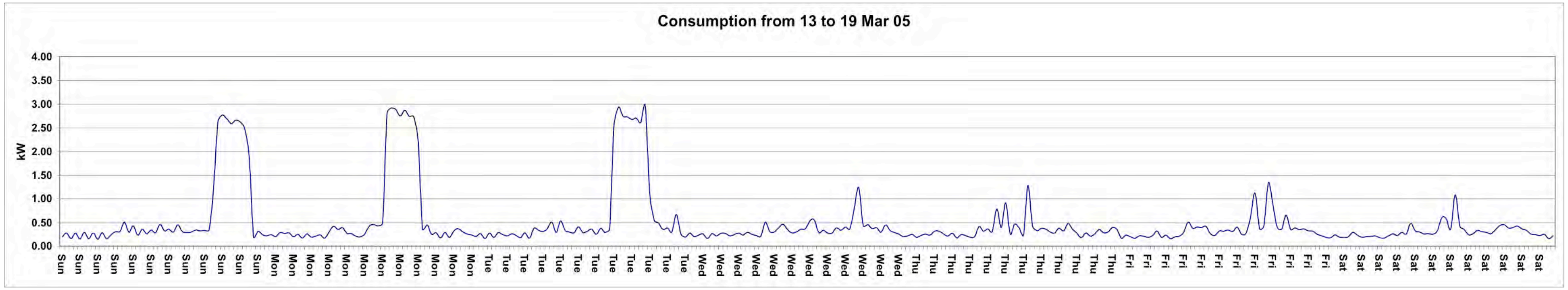


Figure 14: Load profiles for Site 17.



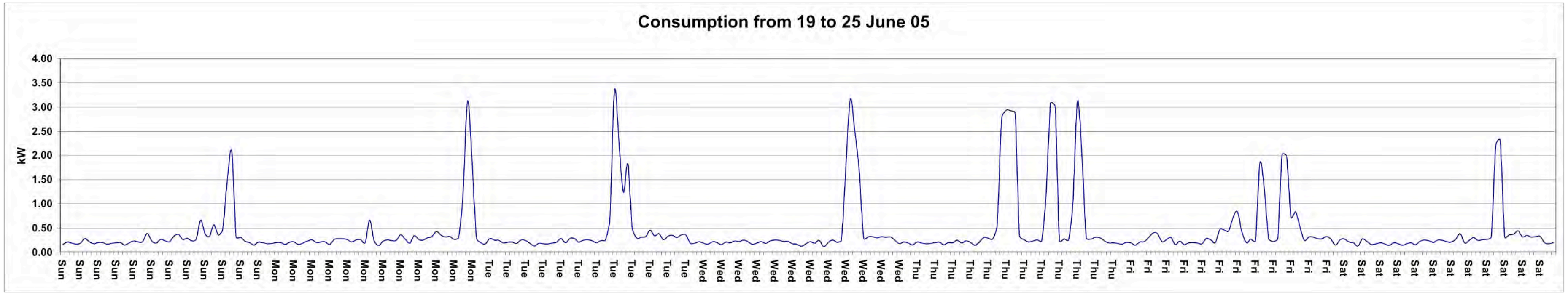


Figure 15: Load profiles for Site 18.

5.1.10 Site 19

Figure 16 gives the load profiles for Site 19. The minimum demand at Site 19 is above average, but the peaks are below average, particularly in winter. The home is occupied by four adults – a male and female in their forties and two males in their twenties. The load profile is characterised by obvious flat periods when it is likely that nobody is home. Indeed, the survey data indicated that the house is typically unoccupied during the day on weekdays.

Site 19 has the lowest number of appliances and fixtures, although the low number of lights reported (five) is likely to be erroneous. However, the occupants reported that they have replaced their solar water heater with an electric water heater. This explains why the minimum demand is relatively high, as the electric water heater will use energy overnight when demand would otherwise fall closer to zero.

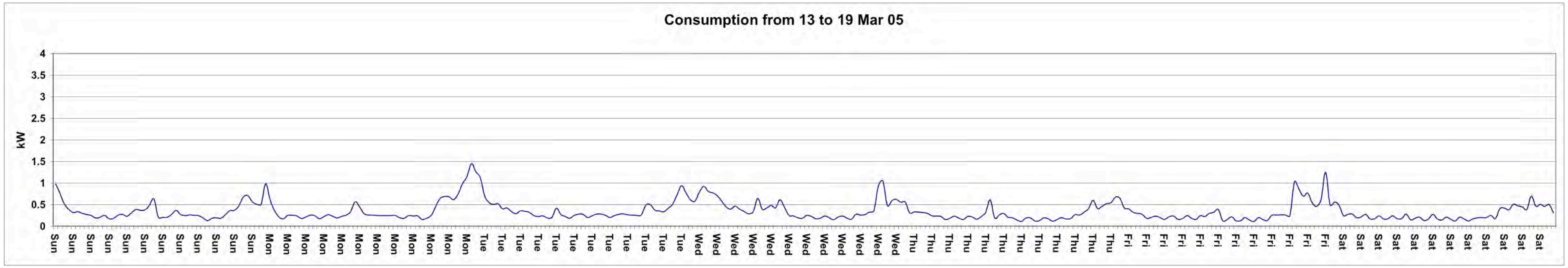
The household has two portable fans and two portable air conditioners that are used in summer when the temperature is above 30°C. The peaks in the summer load profile appear to correspond to times when the air conditioners were used. There are no electric heaters in the household, which helps to explain the lower peaks in the winter profile. Peaks in both summer and winter tend to occur in the evening, when the house is fully occupied and the computer and home entertainment equipment are in use.

5.1.11 Site 20

Figure 17 gives the load profiles for Site 20. Minimum, average and peak demand at Site 20 are generally below average for the sample, with the exception of winter peak demand, which is above average. Peaks, particularly in winter, are quite sharp and distinct.

The house is occupied by a male and female in their twenties. Nobody is usually home between 9am and 3pm, one person is home between 3pm and 6pm and both are home after 6pm. The low levels of demand can be explained by the small household size and the relatively low occupancy rate.

The peaks occur in the evenings, when both occupants are home, home entertainment equipment and cooking appliances are in use, and heaters or air conditioners are being used. The household has three portable air conditioners and a refrigerative air conditioner, however it appears that the refrigerative air conditioner was installed after the metering date. Consequently, the observed summer peaks coincide with use of the portable air conditioners. The household also has a fan heater that is used in winter and the winter peaks likely coincide with use of the fan heater.



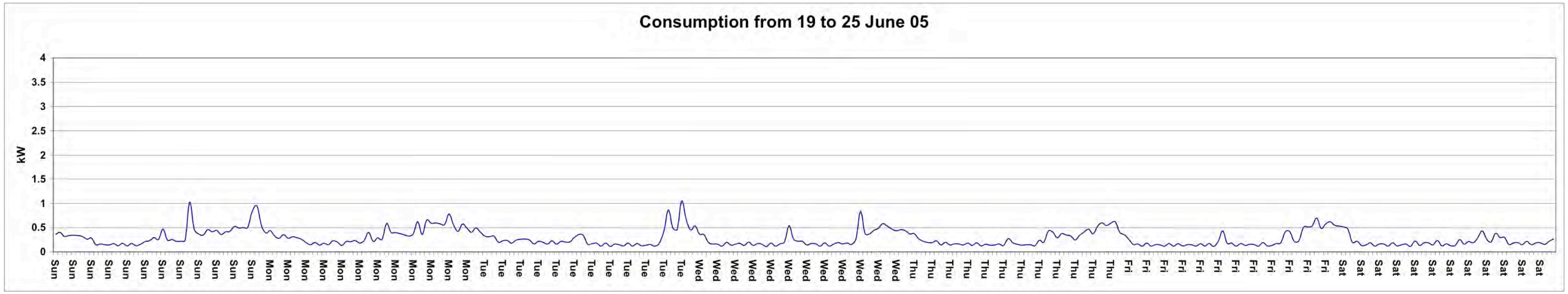
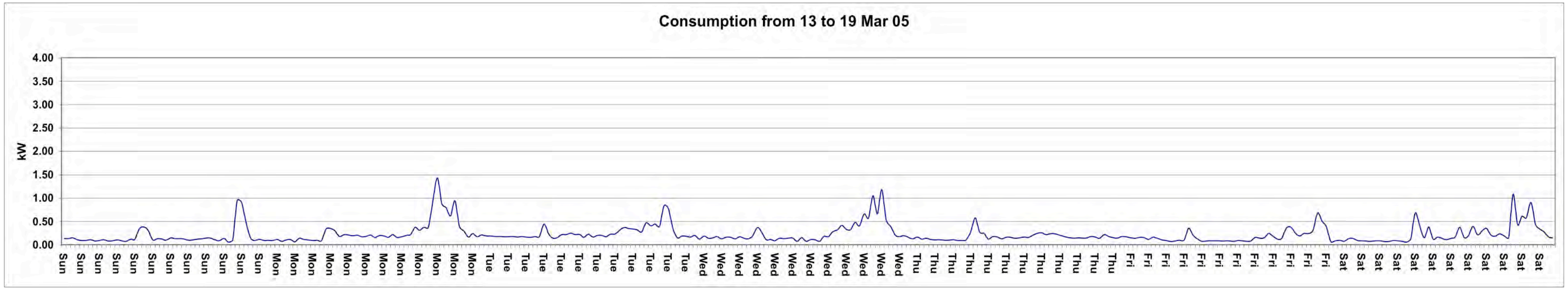


Figure 16: Load profiles for Site 19.



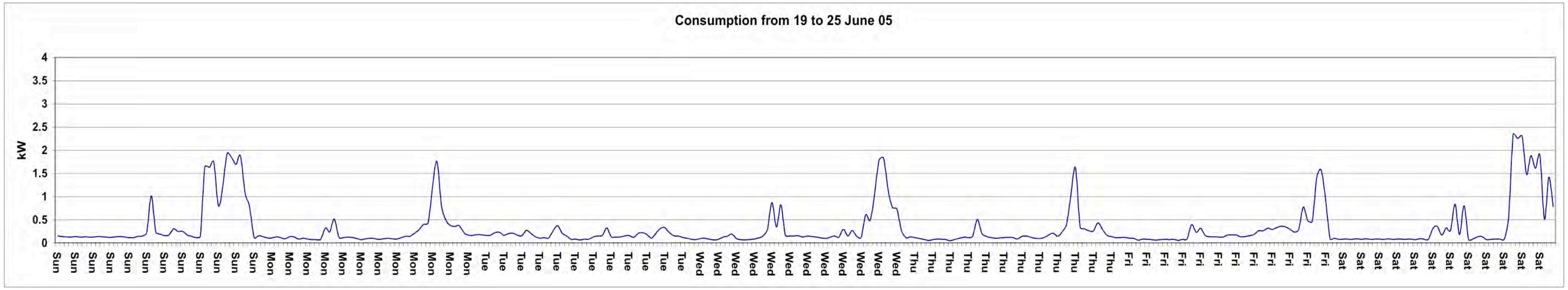


Figure 17: Load profiles for Site 20.

5.1.12 Site 21

Figure 18 gives the load profiles for Site 21. Average demand is below average in summer but significantly above average in winter. Peak demand is well below average in summer and around the average in winter. Minimum demand is close to the average. The summer load profile shows small, regular peaks, while the winter profile has more frequent peaks that are less regular.

The household has three occupants – a couple in their thirties and a five-year old child. Both adults are home during the day on Mondays and Tuesdays and one is home on the other weekdays. The child is away from home between 9am and 3pm, either at school or pre-school.

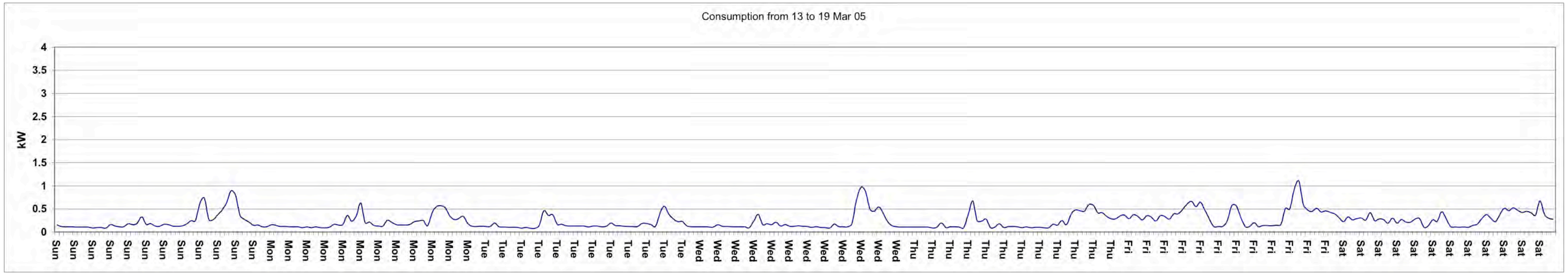
The household has an evaporative cooler that is used from midday to 11pm on very hot days. The higher summer peaks, approaching 1 kW, probably occur when the cooler is in use. Smaller summer peaks correspond to normal evening use of home entertainment equipment, a computer and cooking appliances.

The household also has two radiant heaters and an oil heater that are used overnight, from 9pm to 9am, on very cold days. This explains the relatively constant overnight demand of about 0.4 to 0.6 kW. Morning and evening peaks are superimposed on this constant heating demand, explaining the higher overall peaks in winter.

5.1.13 Site 24

Figure 19 gives the load profiles for Site 24. Average demand is above average in summer but below average in winter. Peak demand is below average in both summer and winter. Minimum demand is above average in summer but well below average in winter. The winter load profile shows an abrupt drop in the minimum demand midway through the week.

The house is currently occupied by a male and a female, aged 27 and 31 respectively. However, after comparison of the survey and metering data, and closer examination of the full metering dataset, it appears highly likely that there has been a change of occupancy at this site since the period represented in the load profiles. Close examination of the data collected during May and June shows an abrupt change in the load profile, with a fall in the minimum demand and an increase in the peak demand. Consequently, a case study has not been developed for this site.



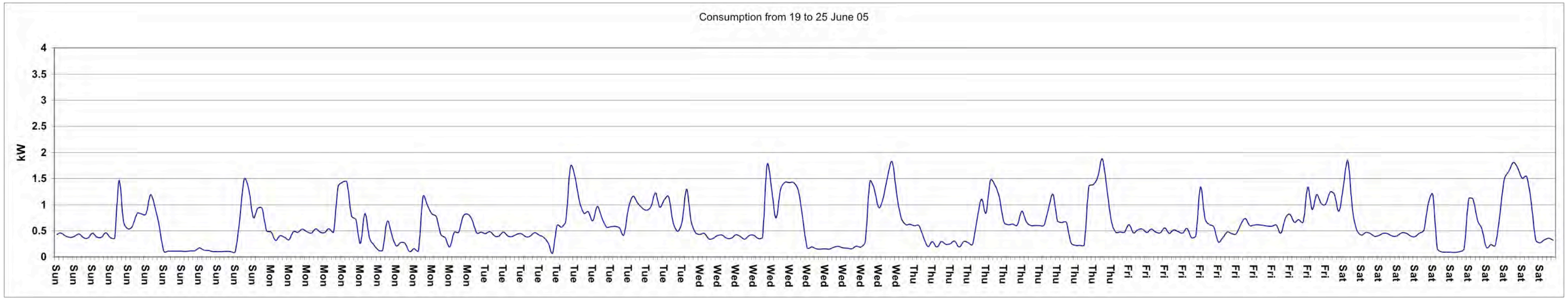
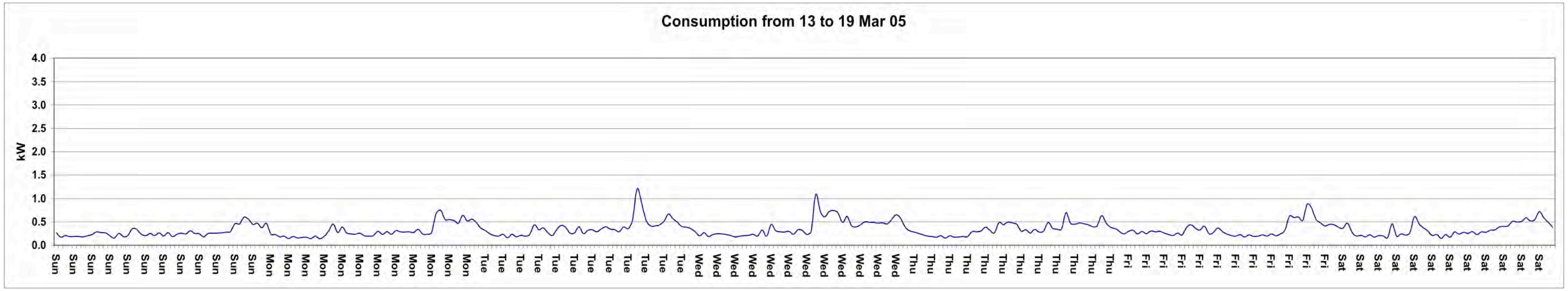


Figure 18: Load profiles for Site 21.



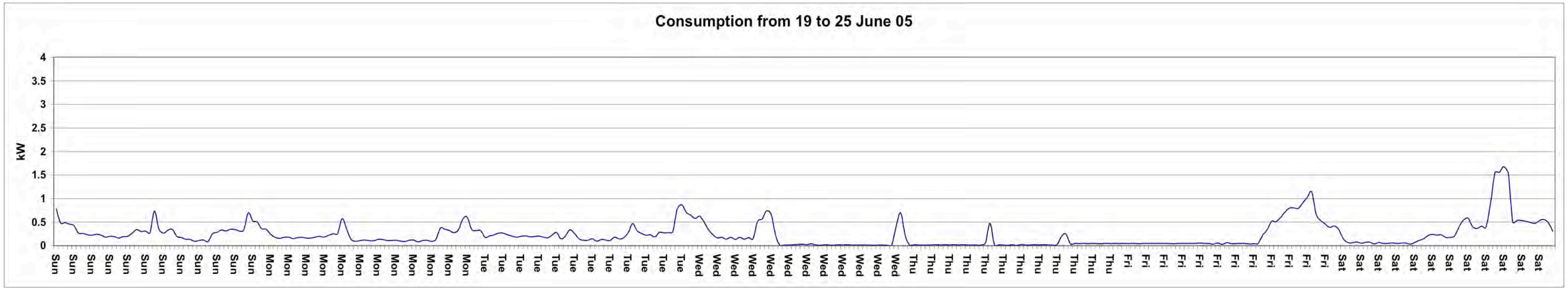


Figure 19: Load profiles for Site 24.

5.1.14 Site 25

Figure 20 gives the load profiles for Site 25. Average demand and minimum demand are both below the sample average in summer and winter. Peak demand is below average in summer but above average in winter. The summer demand profile is very flat, with most peaks reaching no more than 0.4 kW but two larger peaks also evident. The winter demand profile has much larger, distinct peaks.

The household has two occupants – a couple in their thirties. They are away from home during the day, every day. This explains the long periods of low demand in both summer and winter, averaging about 0.1 kW. The low levels of minimum demand may also be explained by the priority given to energy conservation. The household has a high number of low-watt lights installed and tended to agree or strongly agree with statements testing environmental concern and commitment to saving energy.

The household has three ceiling fans, a portable fan and an evaporative cooler. However, it appears that only the ceiling fans are used, any only for short periods in the evening. The relative lack of large peaks in the summer profile is due to the lack of air conditioning. It may be that the fans were not used during this period either, except for the periods when the two larger peaks occurred.

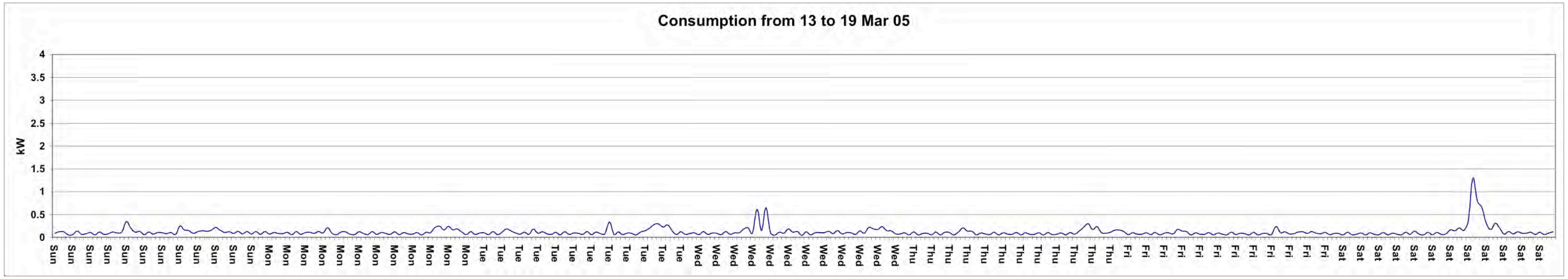
The household had a convection heater, which has now been replaced with two gas heaters. It appears likely that the convection heater was still in use when the June load profile was measured and that use of the heater explains the regular spikes in the graph.

5.1.15 Site 26

Figure 21 gives the load profiles for Site 26. As discussed in Section 7.1, it appears that Site 26 was unoccupied during the June metering period. This case study therefore focused on the March load profile. Minimum demand and average demand are both above average in the March load profile, but peak demand is close to the average. The profile is characterised by irregular peaks of variable duration and height.

The household comprises three adults, with ages ranging from 32 to 18. Occupancy patterns during the day appear to be irregular. Sometimes people work from home on a computer. Other times there is nobody home during the day. The irregular peaks are likely linked to these occupancy patterns.

The household has three portable fans, which are used overnight on hot days. This prevents minimum demand from falling to very low levels during the night, which explains the relatively high level of minimum demand. Peaks seem to be related to the use of computers and home entertainment equipment, including a flat screen television and home theatre system, in the evenings and during the day.



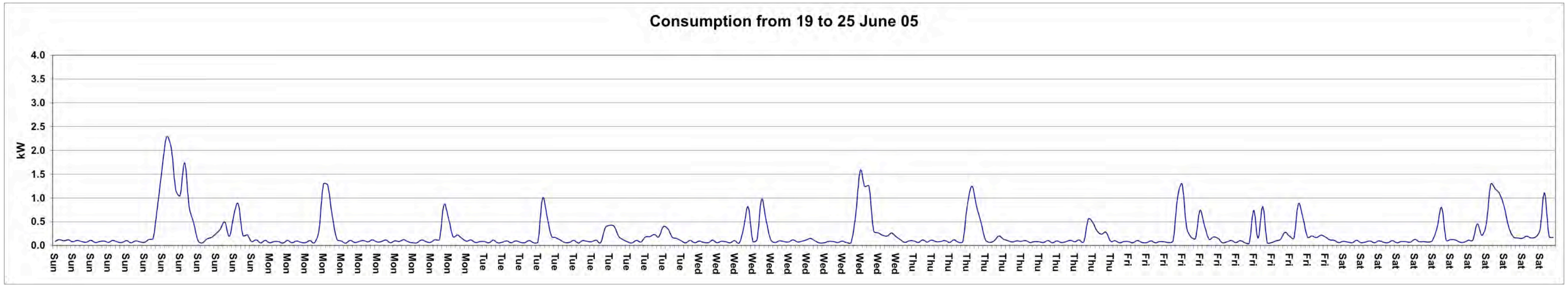
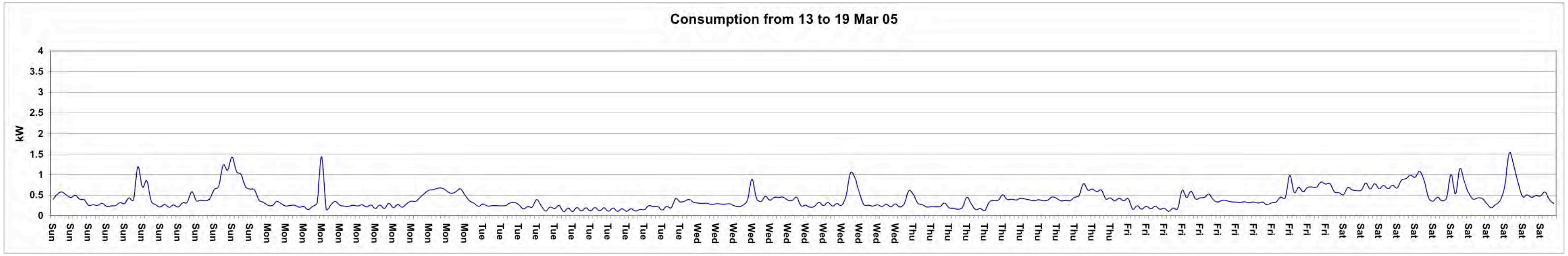


Figure 20: Load profiles for Site 25.



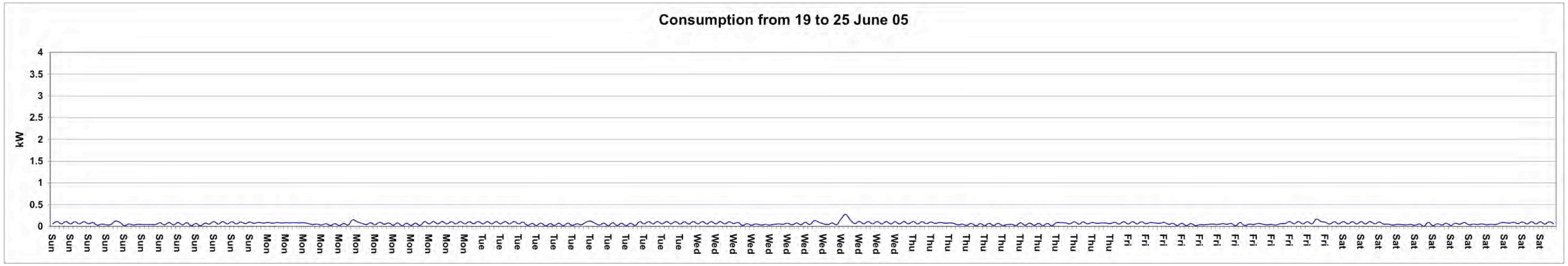


Figure 21: Load profiles for Site 26.

6 HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS

This section provides a demographic analysis of the study sample. Demographic characteristics of the study households and their members are compared with those for Sydney as a whole (or NSW where figures for Sydney could not be located). Unless otherwise specified, all Sydney data is taken from ABS *2001 Census data, Basic Community Profile and Snapshot, 105 Sydney*, and *Expanded Community Profile, Sydney*. Where figures have been calculated from ABS data tables, this is indicated by a footnote. All references to Sydney are to the ABS Sydney Statistical Division.

The characteristics of age, gender, household size and structure, dwelling size, household income, house ownership, disability and language spoken at home are explored in detail below.

6.1 Age

Table 4 shows the proportion of household members in the study sample in each age bracket, compared with Sydney as a whole. The median age for the study sample is 34 years, which is also the median age for Sydney as a whole. However, the age breakdown differs from that of Sydney as a whole, with people aged under 14 years and over 65 years being under represented, and people aged in the 25-44 years age bracket being over represented.

	Age bracket				
	0-14 years	**15-24 years**	**25-44 years**	**45-64 years**	**65 years +**
Study sample	10.53%	18.42%	44.74%	21.05%	5.26%
Sydney	20.2%	14.0%	31.7%	22.2%	11.9%

Table 4: Age profile of household members

6.2 Gender

The study sample comprises 57.9% males and 42.1% females. Males are over represented compared to Sydney as a whole (where males comprise 49.23% and females 50.77% of the population).

6.3 Household size

The mean household size for the study sample is 2.53 persons. This is slightly smaller than the mean household size of 2.7 for Sydney as a whole.

6.4 Household structure

Table 5 shows the proportion of each household structure type in the study sample, compared with Sydney as a whole. In the study sample, couple-families without children are over represented (40% of the sample) compared to Sydney as a whole (where they represent 23.23% of all occupied private dwellings). Couple-families with children are under represented (20% compared to 37.58% for Sydney). Group households are over represented (20% of the sample, compared to 4.34% for Sydney) and lone person households under represented (13.33% compared to 22.37%).

Household structure	Study sample (%)	Sydney[3] (%)
Couple families with children	20	37.58
Couple families without children	40	23.23
One parent families	0	10.93
Other families	6.67	1.56
Group households	20	4.34
Lone person households	13.33	22.37

Table 5: Household structure of participating households

6.5 Dwelling size (number of bedrooms)

If dwelling size is measured by the number of bedrooms, the dwellings in the sample can be described as being of average size for NSW. The average number of bedrooms in the sample is 3.2, compared to 3 for NSW as a whole.[4] All the dwellings in the sample had either 3 or 4 bedrooms. The mode (most common) number of bedrooms in the sample is 3 (twelve of the fifteen dwellings have 3 bedrooms).

6.6 House ownership / tenure

The study sample contained a much lower than average proportion of rental dwellings. In the study sample, 73.33% of the dwellings were either owned or being purchased, while 6.67% were being rented.[5] This compares with figures for Sydney as a whole, where 62.7% of all occupied private dwellings are either owned or being purchased and 29% are being rented.

6.7 Household income

Table 6 provides a breakdown of household incomes in the study sample compared to Sydney households. The study sample is not typical of Sydney household income, but rather is skewed towards the higher income brackets. In particular, it should be noted that the 26.96% of Sydney households with a weekly income of $399 or lower are not represented in the sample at all. Further, while only 35.29% of all Sydney households have a weekly income of more than $1,200, this income bracket accounts for 73.33% of the study sample.

The Sydney median weekly household income is $800-999. The median weekly income for the sample households is in excess of $1,400.

[3] Sydney figures calculated from ABS 2001 Census data, Expanded Community Profile, Sydney, Table X47. Figures represent the percentage of all occupied private dwellings.

[4] ABS Australian Social Trends 2005, Housing, National and state housing summary tables.

[5] Three households or 20% described their tenure as ‘other’.

	Weekly income ($ range)							
	<200	200-399	400-599	600-799	800-999	1000-1199	1200-1399	1400+
Sample[6] (%)	0	0	0	6.67	6.67	6.67	20	53.33
Sydney[7] (%)	4.24	12.63	10.09	9.19	8.42	8.44	8.22[8]	27.07

Table 6: Household weekly income

6.8 Language spoken at home

Compared to Sydney as a whole, the study sample contains a much higher than average proportion of people who speak a language other than English at home. Whereas 27.26% of Sydney residents speak a language other than English at home[9], 60% of the study sample report doing so – more than double the Sydney average.

6.9 Disability

No households in the sample reported having any members with a disability. This compares with a disability rate of 19.3% for NSW as a whole.[10]

6.10 Conclusions

The demographic analysis shows that the study sample is not typical of Sydney households with respect to the characteristics examined. The median age of household members, which matches that of Sydney residents, is the only exception.

In general, the study sample can be characterised as including a disproportionately high number of adults of working age, males, small households, couples without children, group households, owner occupiers, households with high income and people who speak a language other than English at home. It has a disproportionately low number of young and elderly people, females, couple-families with children, lone person households, tenants and people reporting a disability.

[6] Percentages are of the whole study sample. However, percentages do not total 100, as one survey respondent did not state household income.

[7] Sydney percentages calculated from Basic Community Profile, Sydney, Table B31: Weekly household income by household type (occupied private dwellings).

[8] This figure corresponds to the ABS income bracket '$1200-1499'. Hence, this figure is not directly comparable with study sample.

[9] Calculated from ABS 2001 Census data, Basic Community Profile, 105 Sydney, table B08. Does not include overseas visitors or responses where language spoken at home is 'not stated'.

[10] Source: ABS 4430.0 2003 Disability, Ageing and Carers, Australia: Summary of Findings. Comparison is to NSW as a figure for Sydney could not be located. The NSW disability rate used here is for 1998; the most recent figure that could be located (there was no question relating to disability in the 2001 Census).

Given the significant differences between the demographic characteristics of the sample as those of Sydney as a whole, it is not recommended to assume that any of the relationships observed in this study will hold across Sydney. However, the results of this study do provide an indication of the degree of variation in electricity consumption patterns that might be expected in other parts of Sydney. Further, the study draws out some of the key behavioural, demographic and infrastructure-related factors that might contribute to this variation. Further research with larger sample sizes and greater representativeness would be required to develop results for Sydney as a whole.

7 STATISTICAL ANALYSIS

This section discusses the results of the statistical analysis undertaken to link the survey data to the metering data. Section 7.1 identifies some issues with the content of the survey sample that need to be considered in subsequent analysis. Section 7.2 reports on some basic linear regression undertaken to test some initial theories about the reasons for observed variations in the load profiles. Section 7.3 discusses the results of multiple regression analysis used to link the survey data to the metering data. Finally, Section 7.4 summarises results on attitudes, opinions and awareness.

7.1 Sample issues

Given the small size of the sample of metered households, and the even smaller size of the sample of survey respondents, the analytical results presented below are not expected to be statistically representative of conditions in larger geographic areas, such as Newington or Sydney. However, it is likely that the sample of 15 survey respondents is reasonably representative of the larger sample of 30 metered households. The response rate of 50% is high enough to expect that a large proportion of the variation in the larger sample will be captured in the survey sample. Further, the graphs in Section 4.3 indicate that the average metering variables for the 15 respondent households are reasonably similar to those for the full sample of 30 households.

However, although the survey sample is likely representative of the metered sample, it is important to identify any data issues that may distort the sample and reduce its representativeness. Distortion could occur if any of the respondent households were unoccupied during the period for which metering data are available, if occupancy has changed between the period of metering and the time when the survey was completed, if there were problems with the interval meters, or if there were major alterations or additions to the home between the period of metering and the time when the survey was completed.

From a review of the metering data, it appears likely that one of the respondent households (Site 26) was unoccupied during the June metering period. The winter load profile for Site 26 shows relatively constant demand at a low level of less than 0.2 kW, with average demand of only 0.07 kW. By comparison, the March graph for the same site shows clear peaks with minimum demand generally above 0.2 kW and average demand of 0.41 kW. To avoid sample distortion, data for this site are excluded from the June analysis. This reduces the size of the June sample to 14 households.

The metering data also indicate that the interval meter on the PV panel at Site 11 was faulty. This meter recorded no data. So that Site 11 can still be used in the analysis, we have assumed that the output from the PV panel would be identical to the output from the PV panel at the home immediately next door to Site 11. The neighbouring panel would receive very similar solar input and may only differ slightly in its electricity output due to efficiency variations.

Given the need to limit the length of the survey, we did not include any questions designed to test for a change in occupancy or home alterations between the metering period and the time of survey completion.[11] Consequently, recent occupancy change and recent alterations are possible sources of sample distortion. This should be taken into account when interpreting the results.

[11] In hindsight, it would have been appropriate to include a question on how long the householder had lived at their current address. This type of question should be included in any future studies of this type.

7.2 Linear regression

Based on our past experience with social research on energy consumption, we had some initial expectations about the reasons for the observed variations in the metering data. Specifically, we anticipated that:

- Average electricity demand might be closely related to household size, as the number of people in a household tends to increase the energy consumption
- Average electricity demand might be closely related to the number of bedrooms, as dwelling size influences energy required for space heating and cooling
- Average electricity demand might be closely linked to the level of daytime occupancy, as homes that are used constantly would consume more energy than homes that are unoccupied during the day
- Peak electricity demand in March might be closely linked to the presence of air conditioning, as air conditioning has been identified as a significant and growing load on the network during peak summer periods
- Peak electricity demand in June might be closely linked to the presence of electric heaters.

To test these initial theories, we developed several data plots to support linear regression.

7.2.1 Average demand

First, we plotted average electricity demand in March and June against household size. The results for March are shown in Figure 22 (June results were similar). While there is an apparent trend for average demand to increase with household size, this trend is outweighed by the significant variation observed for households of the same size. For example, average demand is almost five times higher for the two-person household with the highest consumption compared to that with the lowest consumption. Further investigation was therefore required to identify additional reasons for the variation across households.

Figure 23 plots the variation in average demand in March against the number of bedrooms. In this case, there was evidence for a decrease in average demand as the number of bedrooms increases. However, as our sample only includes homes with three and four bedrooms, and only three households had four bedrooms, this trend is unconvincing. Again, the variation in average demand across households with the same number of bedrooms was large.

Figure 24 plots the variation in average demand in March against an approximate measure of daytime occupancy (the number of person hours spent at home between 9am and 6pm) derived from the survey responses. The trend towards an increase in average demand with greater daytime occupancy is the most significant of the three examined so far, based on the R^2 value. However, daytime occupancy still only explains 13.7% of the observed variation in average March demand.

It is apparent that average demand cannot be easily explained using single variables. Rather, multiple variable regression is required to identify the set of variables that contribute to variation in average demand. The results of the multiple regression analyses undertaken during this study are described in Section 7.3.

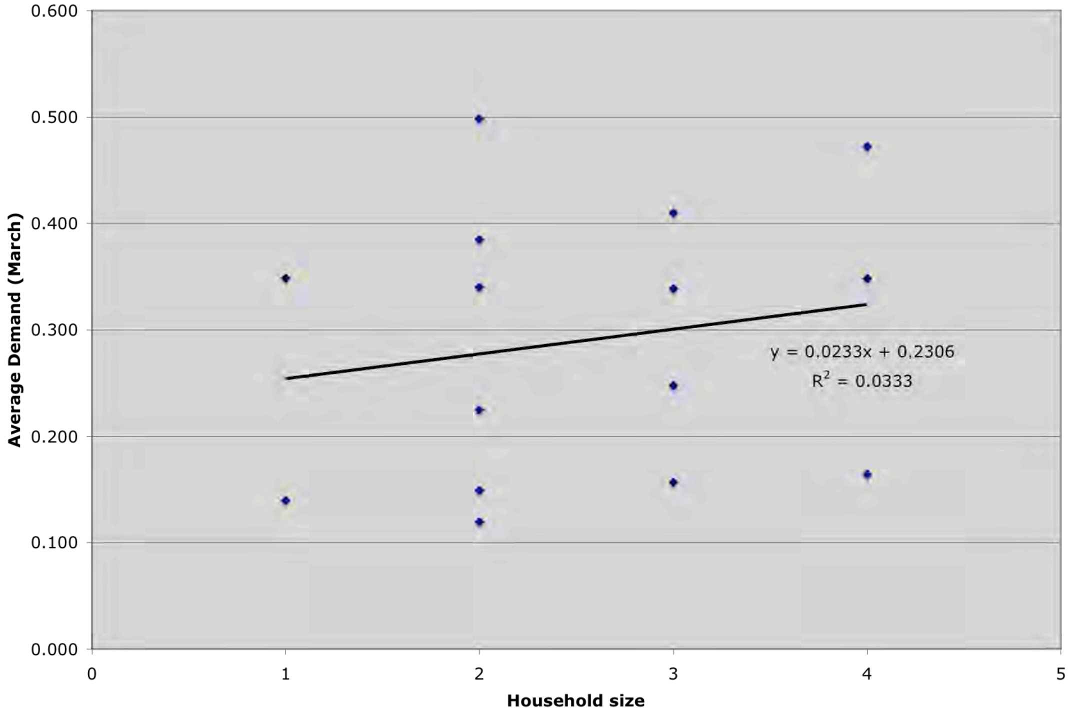


Figure 22: Variation of average demand in March with household size.

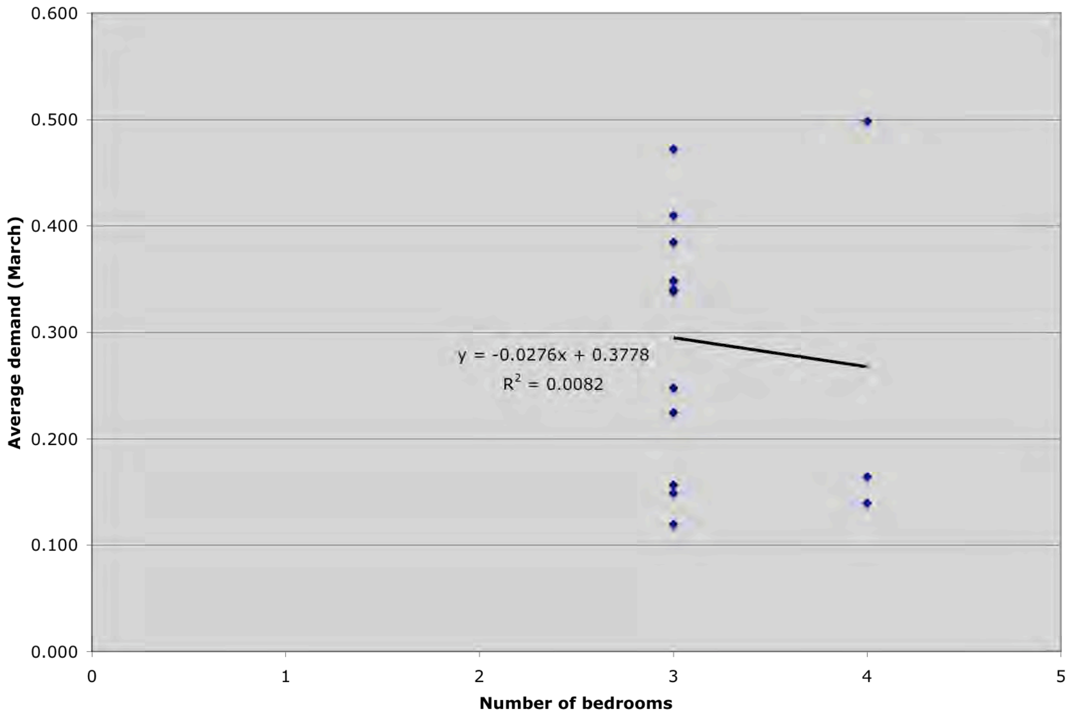


Figure 23: Variation of average demand in March with number of bedrooms.

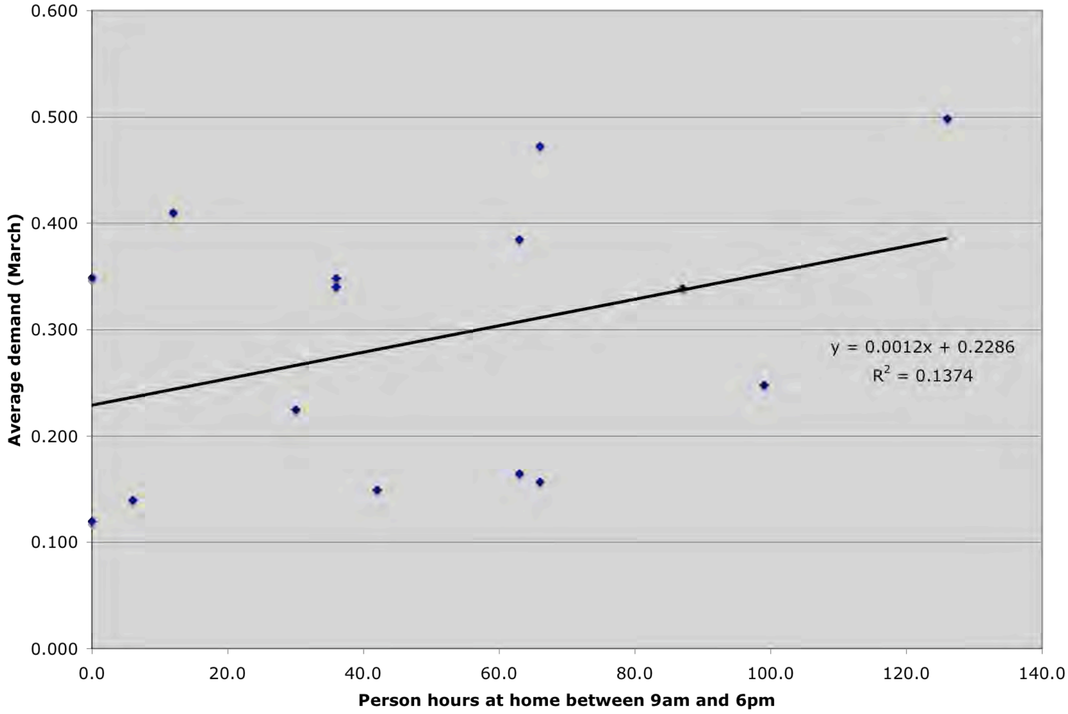


Figure 24: Variation of average demand in March with daytime occupancy.

7.2.2 Peak demand

Figure 25 plots the variation in peak demand in March with the presence of an air conditioner. Although there is a clear trend towards higher peak demand in those households with an air conditioner, it is also apparent that some households with air conditioners have lower demand than households without air conditioners. This indicates that other factors are also important in determining peak demand in March, and that multiple regression analysis is therefore appropriate.

Similarly, Figure 26 plots the variation in peak demand in June with the number of electric heaters present. The trend here is less clear, with some households with no electric heaters having relatively high peak demand and some with one, two or three heaters having relatively low peak demand. Clearly, other factors (such as actual use of the heaters) are important and need to be considered through multiple regression analysis. Section 7.3 reports the results of multiple regression analysis undertaken during this study.

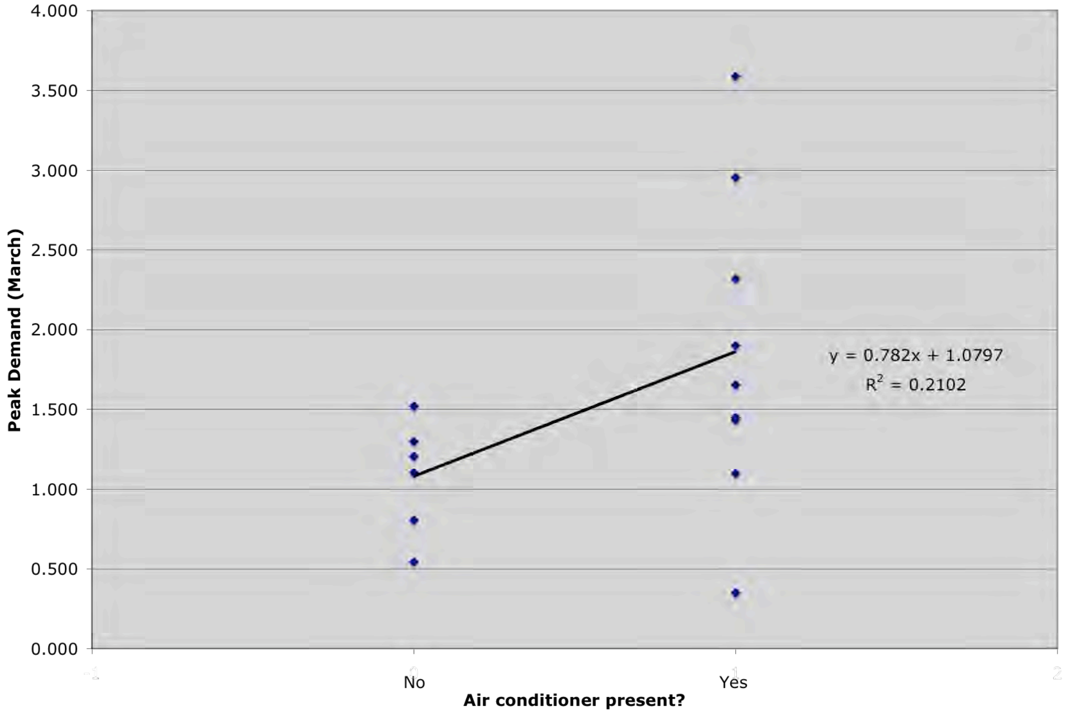


Figure 25: Variation of peak demand in March with the presence of an air conditioner.

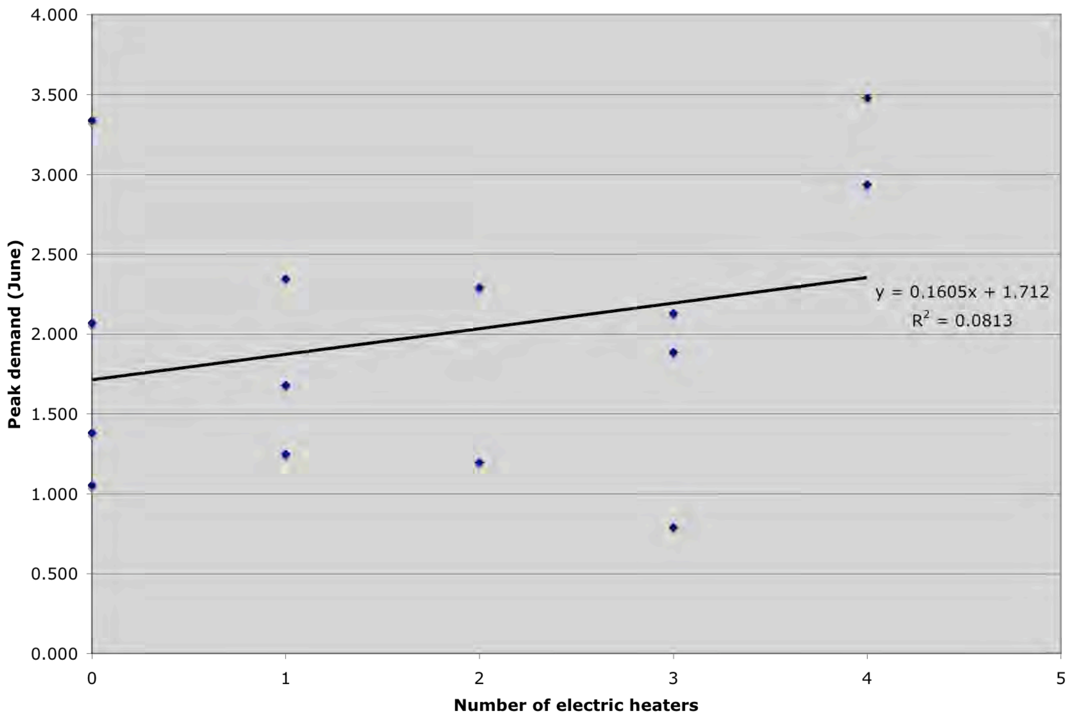


Figure 26: Variation of peak demand in June with the number of electric heaters.

7.3 Multiple regression analysis

As discussed in Section 2.4.3, we used multiple regression methods to identify those survey variables that best explained the variation in key metering variables. Specifically, we sought to identify those survey variables that explained the variation in average demand and peak demand. Separate analyses were undertaken for March and June data. Results are discussed in the sections below. Appendix 4 provides a detailed explanation of the multiple regression methodology.

7.3.1 Average demand (March)

The survey variables that best explained average demand in March are shown in Table 7, in order of importance.[12] As discussed in Appendix 4, multiple regression methods attempt to fit an equation to the available data of the form:

$$y = b + m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4 + \ldots$$

In this case *y* is the average demand in March. The constant (*b*) is shown in the first row in Table 7. The regression coefficients (m_1, m_2 etc) are shown in the second column of Table 7. Finally, the x-variables are the survey variables shown in the first column.

Survey Variable	Regression Coefficient (*m*)	Minimum Contribution (kW)[13]	Maximum Contribution (kW)[14]
Constant (*b*)	0.4715	0.472	0.472
Number of person hours home during the day	0.00267	0	0.336
Always turn lights off when not using them	-0.150	-0.45	-0.75
Actively try to save energy around the house	0.137	0.411	0.685
Weekly household income ($)	-0.00017	-0.119	-0.255

Table 7: Regression results for average demand (March).

The third and fourth columns in Table 7 show the minimum and maximum contribution of each survey variable to the average demand in March. These are the numbers you obtain when you multiply the smallest and largest value of the x-variable by the regression

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[12] Only those variables that made a statistically significant contribution to average demand, at a significance level of 10%, are shown. In other words, there is less than a 10% chance that the relationship between each of the variables in the table and average demand in March occurs by random chance.

[13] The minimum contribution is calculated by multiplying the regression coefficient by the smallest value of the survey variable in the sample.

[14] The maximum contribution is calculated by multiplying the regression coefficient by the largest value of the survey variable in the sample.

coefficient (*m*). They provide an indication of how much difference each survey variable can make to the average demand in March.

The regression model summarised in Table 7 accounts for 66.8% of the observed variation in average demand in March, This is a reasonable result, given the small sample size.[15]

The analysis confirms that there is a positive correlation between the number of person hours during which the home is occupied during the day (between 9am and 6pm) and average demand. This makes sense, as households that have members at home during the day will have higher average demand than those households in which people are away from home (and using energy elsewhere). This variable has the greatest influence on average demand in March, in terms of the difference between the minimum and maximum contribution to demand.

Table 7 also indicates that there is a negative correlation between average demand and agreement with the statement 'I always turn off lights when they are not being used'. That is, demand decreases as people make more effort to turn off lights. This makes sense and offers some encouragement that turning off lights does have an impact on electricity use. However, it may be that responses to this question also act as a proxy for a whole range of other energy saving actions, beyond turning off lights.

There is also a positive correlation between average demand and agreement with the statement 'I actively try to save energy around the house'. It seems strange, at first glance, that households that are actively trying to save energy have higher average demand. However, after further consideration, it makes sense that those households with the highest energy consumption (and largest bills) would be most motivated to try to save energy. Our data might indicate that the motivation to save energy has not been readily translated into significant reductions, perhaps as a consequence of systemic, social or other barriers.

Finally, the analysis indicates that income is negatively related to average demand. That is, average demand falls as income increases. This is the opposite of the relationship that is usually thought to hold between income and energy consumption. A possible explanation for this finding is that households with higher income are more able to afford efficient appliances and that this leads to lower average energy consumption. Another possibility is that households with higher income are more able to afford to eat away from home and spend time pursuing leisure and entertainment interests, which means that they spend less time at home using energy. However, further research would be necessary to confirm these possible explanations.

7.3.2 Average demand (June)

The survey variables that best explained the variation in the average demand in June are shown in Table 8, in order of importance. The regression model accounts for 72.4% of the observed variation in average demand in June. Again, this is a reasonable result, given the small sample size.

Table 8 indicates that the number of electric heaters in the home and the heating time on a cold day are both positively correlated with average June demand. Heating time is the most important factor, with a difference of 0.667 kW between those homes that do not use electric heaters and those that use heaters for the longest period of time. This highlights the contribution of heating to average demand in winter. Given that these homes are fitted with

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[15] In technical terms, the regression equation has an adjusted R^2 of 0.668.

natural gas heating, it would be reasonable to expect an even more significant contribution from electric heating in homes that are not fitted with gas.

Survey Variable	Regression Coefficient (*m*)	Minimum Contribution (kW)	Maximum Contribution (kW)
Constant (*b*)	0.3797	0.38	0.38
Duration of heating time on a cold day (hours)	0.0303	0	0.667
Always turn lights off when not using them	-0.28	-0.84	-1.4
Actively try to save energy around the home	0.254	0.762	1.27
Number of electric heaters	0.058	0	0.232

Table 8: Regression results for average demand (June).

As observed in the March data, there is a positive correlation between average demand and agreement with the statement ‘I actively try to save energy around the house’ and a negative correlation between average demand and agreement with the statement ‘I always turn off lights when they are not being used’. This indicates that these two factors are important year round, rather than just in particular seasons.

7.3.3 Peak demand (March)

The survey variables that best explained the variation in peak demand in March are shown in Table 9, in order of importance. The regression equation accounted for 98.89% of the observed variation in peak demand, indicating that these survey variables were able to explain almost all of the observed variation in the metering data.

The factors influencing peak demand are notably different from those influencing average demand. There was positive correlation between peak demand and agreement with the statement ‘I actively try to save energy around the house’. This relationship was also observed for average demand and was explained there. This relationship had the largest influence on peak demand in March.

There was a negative correlation between peak demand and agreement with the statement ‘I have received information about saving energy in the past’. This may indicate that households with knowledge and awareness of the need to save energy are more likely to moderate their discretionary demand, contributing to reduced peak demand. This provides some support for the value of information and awareness campaigns.

The number of refrigerators, reverse cycle air conditioners and high-watt lights are all positively correlated with peak demand. Refrigerators, as they are always on, provide much of the baseline demand that determines how high peak demand can reach. Refrigerators have higher demand in summer periods, when temperatures are higher, so are more likely to contribute to summer peaks than winter peaks. In this study, households with three refrigerators (the highest number observed) have peak demand that is 0.872 kW higher than households with one refrigerator.

The presence of a reverse cycle air conditioner adds in the order of 0.31 kW to the size of observed peaks in summer. The importance of air conditioning is consistent with the data plotted in Figure 25. High-watt lights can add up to 0.389 kW to peaks.

There was a negative correlation between the number of fans present and the peak demand. This indicates that, relative to the rest of the sample, households with more fans are less likely to use air conditioning, and therefore have lower peak demand.

Survey Variable	Regression Coefficient (*m*)	Minimum Contribution (kW)	Maximum Contribution (kW)
Constant (*b*)	-0.8449	-0.845	-0.845
Actively try to save energy around the home	0.582	1.746	2.91
Have received information about saving energy in the past	-0.272	-0.272	-1.36
Number of fridges	0.436	0.436	1.308
Number of person hours home during the day	0.00307	0	0.387
Number of high-watt lights	0.0105	0.032	0.389
Number of reverse cycle air conditioners	0.31	0	0.31
Number of fans	-0.049	0	-0.245

Table 9: Regression results for peak demand (March).

Finally, there was a positive correlation between peak demand and the number of person hours spent at home during the day. Occupancy during the day seems to increase the size of observed peaks, perhaps because there is overlap between energy consumption associated with people working from home and consumption by other occupants returning home from work.

7.3.4 Peak demand (June)

The survey variables that best explained the variation in peak demand in June are shown in Table 10, in order of importance. These variables explained 79.81% of the observed variation in peak demand in June, which is a reasonable result for this sample size. This regression model shows the significant influence of reverse cycle air conditioners (used as heating) on peak winter demand. A reverse cycle air conditioner adds about 1.91 kW to peak demand (in this sample).

Peak demand is also positively correlated with income. Households with higher income are more likely to be able to afford expensive air conditioners, dryers, home entertainment equipment and other appliances that contribute to peak demand.

Finally, peak demand is positively correlated with agreement with the statement ‘I have sought information about saving energy in the past’. As with the correlations observed previously for the statement ‘I actively try to save energy around the house’, it is possible that households that have sought information about reducing their energy bills are those that have the highest demand, and therefore the most incentive to reduce demand. Alternatively, this correlation may be an artefact of the small sample size.

Survey Variable	Regression Coefficient (*m*)	Minimum Contribution (kW)	Maximum Contribution (kW)
Constant (*b*)	-0.6506	-0.651	-0.651
Number of reverse cycle air conditioners	1.91	0	1.91
Sought information about saving energy in the past	0.354	0.354	1.416
Weekly household income ($)	0.00105	0.735	1.575

Table 10: Regression results for peak demand (June).

7.4 Attitudes, opinions and awareness

This section presents the survey results on attitudes, opinions and awareness. Figure 27 summarises the level of agreement with several statements assessing attitudes, opinions and awareness. Respondents tended to agree or strongly agree with most statements, with the exception of ‘I have sought information about saving energy in the past’ and ‘I am actively involved in groups that promote environmental issues’. On average, respondents were neutral about the former statement and disagreed with the latter.

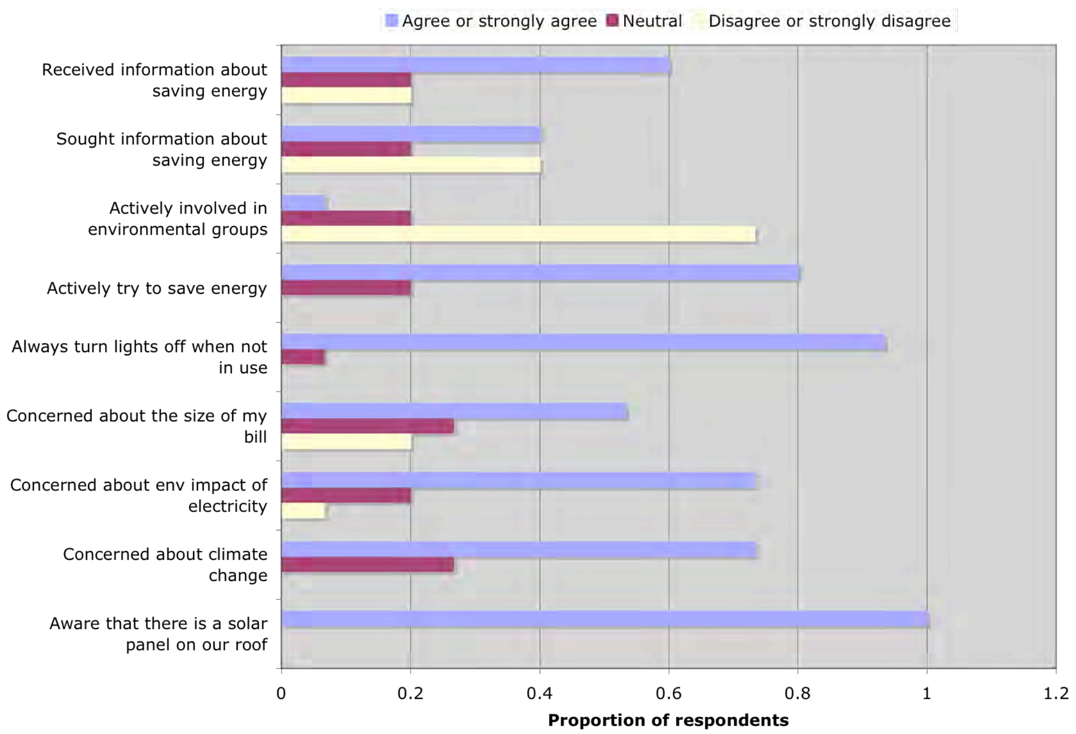


Figure 27: Survey results relating to attitudes, opinions and awareness.

Almost all respondents claimed that they actively try to save energy and always turn lights off when they are not in use. Concern about environmental impacts of electricity use, including climate change, was quite high.

Figure 28 presents the results of several questions about the PV panels and solar water heaters (SWHs) at each site. Most respondents understand how their PV panel works and are aware that it exports to the grid as well as supplying their home. However, fewer were confident that they would know if it stopped working.

One household indicated that their SWH was no longer there, however it was not replaced with an electric water heater, so there was no impact on the load profiles. It may have been replaced with a gas water heater. A second household did not know if their SWH was still present. One household (Site 19) indicated that their SWH was still present but had been replaced by an electric water heater. This has been taken into account in the case study analysis. Finally, only 67% of respondents indicated that they would know if their SWH stopped working.

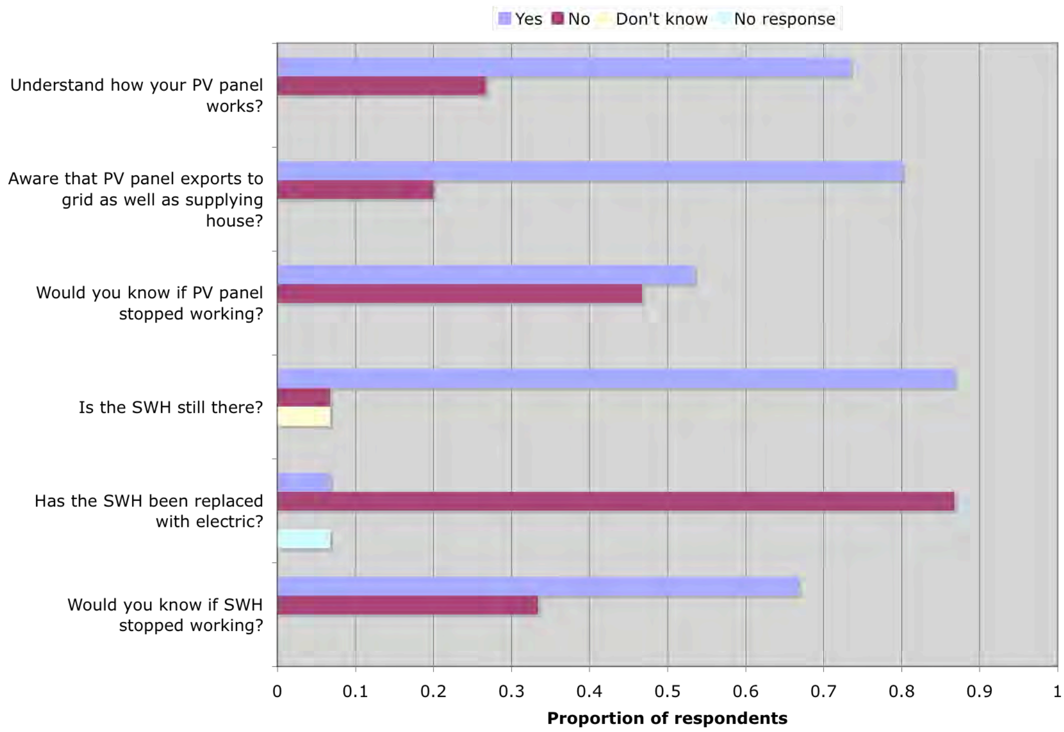


Figure 28: Responses to questions about the PV panel and solar water heater.

8 CONCLUSIONS

The primary objective of this study was to identify the source of large observed variations in electricity consumption patterns in 30 Newington homes with very similar constructed characteristics. The intention was not to develop statistically significant results that could be applied elsewhere in Sydney. Instead, we sought to test a theory that demographics, behaviour and variations in owner-purchased appliances and equipment have a major influence on electricity consumption patterns and peak demand. The study has emphatically confirmed the role of these factors in determining electricity consumption patterns.

8.1 Demand variation

Despite the similarities in construction across the homes, average demand was more than four times greater in the household with the highest electricity consumption compared to that with the lowest consumption. Peak demand was more than ten times greater in the household with the highest peak demand compared to that with the lowest peak demand. Considering that the efficiency of these homes would tend to drive demand down compared to the Sydney average, and that the availability of solar water heating and natural gas heating and cooking would have a similar effect, it is reasonable to assume that homes outside Newington would demonstrate even greater variation in electricity consumption patterns. All-electric homes, in particular, would tend to have higher demand than this sample.

The policy implications are clear – it is not enough to rely on technology to achieve desired reductions in average and peak demand. Policies focused on awareness-raising and behaviour modification, through education, regulation and incentives, are critical to bring about large reductions in average and peak demand.

8.2 Case study findings

The descriptive case studies developed for the 15 participating sites were particularly useful for drawing out the key factors influencing the observed variability in electricity consumption patterns. It quickly became evident that no single variable, or small set of variables, could easily explain the observed variation in load profiles. While most households exhibited a morning peak and a higher evening peak, each household had unique circumstances that affected the timing, size and shape of these peaks.

Nevertheless, some common themes began to emerge from the case study analysis. It was apparent that demographic characteristics alone were a poor predictor of electricity consumption patterns. While household size and structure were important, the behaviours of the household participants were more important. Large households that spent little time at home and used few major appliances commonly had lower average and peak demand than small households that had high occupancy rates and high rates of appliance use.

Behavioural factors with a particular influence on consumption patterns included occupancy patterns (which were influenced by waking and sleeping times, work patterns and whether the household included school children) and space conditioning behaviour (such as differences in temperature tolerance and timing of use of heating and cooling appliances). These factors had a major influence on the timing, size and shape of morning and evening peaks.

The cohort of appliances and equipment present in each household also had a major influence on the shape of the load profiles. In some households, the number of appliances and fixtures seemed to be a good predictor of average demand. However, more generally, the number and type of heating and cooling appliances and home entertainment equipment appeared to have the most influence on peak demand.

Households that had installed air conditioning systems tended to have sharp, distinct peaks in their March load profile, corresponding closely to the time of use of these systems. Households that used fans tended to have flatter profiles. Surprisingly, given the availability of gas heating, most of the households owned electric heaters and these were often used. The peaks generated by winter heating were often as sharp and distinct as those generated by summer air conditioning. Heating and cooling appliances created peaks outside the normal morning and evening peaks when they were used outside these hours.

Home entertainment equipment appeared to contribute strongly to the timing and shape of evening peaks in particular. The biggest peaks tended to occur when people arrived home from work or school and heating and cooling was used in conjunction with home entertainment equipment.

8.3 Statistical analysis findings

The statistical analysis complemented the case study analysis by searching for more formal relationships between average and peak demand and the survey responses. Linear regression was used to search for relationships between average demand and household size, the number of bedrooms and daytime occupancy rates. No convincing relationships were found. Similarly, linear regression was used to examine the relationship between peak demand and the presence of air conditioners and electric heaters. Again, no convincing relationships were found. The linear regression confirmed that no single variable could explain more than a small proportion of the observed variation in average and peak demand.

Given this finding, multiple regression analysis was used to identify the groups of survey variables that were most useful for explaining the variation in average and peak demand. Regression models were identified for average demand in March and June and peak demand in March and June. In summary, the findings were as follows:

- Average demand in March was:
  - Positively correlated with the number of person hours of daytime occupation (between 9am and 6pm).
  - Negatively correlated with agreement with the statement ‘I always turn off lights when they are not being used’. That is, demand decreases as people make more effort to turn off lights.
  - Positively correlated with agreement with the statement ‘I actively try to save energy around the house’. That is, households with the highest energy consumption (and largest bills) are most motivated to try to save energy.
  - Negatively correlated with household income. That is, average demand fell as income increased. A possible explanation for this finding is that households with higher income are more able to afford efficient appliances and that this leads to lower average energy consumption. Another possibility is that households with higher income are more able to afford to eat away from home and spend time pursuing leisure and entertainment interests, which means that they spend less time at home using energy.
- Average demand in June was:
  - Positively correlated with the number of electric heaters in the home and the heating time on a cold day. Heating time had the greatest influence.

    - Positively correlated with agreement with the statement 'I actively try to save energy around the house'.

    - Negatively correlated with agreement with the statement 'I always turn off lights when they are not being used'.

- Peak demand in March was:

    - Positively correlated with agreement with the statement 'I actively try to save energy around the house'. This relationship, which was also observed for average demand, was the largest influence on peak demand in March.

    - Negatively correlated with agreement with the statement 'I have received information about saving energy in the past'. This may indicate that households with knowledge and awareness of the need to save energy are more likely to moderate their discretionary demand, contributing to reduced peak demand. This provides some support for the value of information and awareness campaigns.

    - Positively correlated with the number of refrigerators. Refrigerators, as they are always on, provide much of the baseline demand that determines how high peak demand can reach. Refrigerators have higher demand in summer periods, when temperatures are higher, so are more likely to contribute to summer peaks than winter peaks.

    - Positively correlated with the number of high-watt lights.

    - Positively correlated with the presence of a reverse cycle air conditioner.

    - Negatively correlated with the number of fans present. This indicates that, relative to the rest of the sample, households with more fans are less likely to use air conditioning, and therefore have lower peak demand.

    - Positively correlated with the number of person hours spent at home during the day. Occupancy during the day seems to increase the size of observed peaks, perhaps because there is overlap between energy consumption associated with people working from home and consumption by other occupants returning home from work.

- Peak demand in June was:

    - Positively correlated with the number of reverse cycle air conditioners (used as heating). This had the most significant influence on peak winter demand.

    - Positively correlated with income. Households with higher income are more likely to be able to afford expensive air conditioners, dryers, home entertainment equipment and other appliances that contribute to peak demand.

    - Positively correlated with agreement with the statement 'I have sought information about saving energy in the past'. As with the correlations observed previously for the statement 'I actively try to save energy around the house', it is possible that households that have sought information about reducing their energy bills are those that have the highest demand, and therefore the most incentive to reduce demand. Alternatively, this correlation may be an artefact of the small sample size.

One of the most interesting findings to emerge from the statistical analysis is the correlation between measures of attitudes and awareness and measures of demand. It was not just demographics, behaviour and fixtures that determined demand. A commitment to turn off lights can significantly influence demand, as can receiving information about saving energy.

8.4 Discussion

Although this study used a small sample of households in a distinctive area of Sydney, the results are sufficient to support the theory that behaviour, habits and lifestyle have a major impact on patterns of electricity consumption. By examining a situation where the design features of the homes were relatively constant, it has been possible to draw out the importance of non-design features. Given the efficiency of these homes and the use of solar water heating and natural gas, it is entirely reasonable to expect even greater variation in electricity consumption patterns in other areas of Sydney.

The variables that appear to have the most value in predicting average demand are:

- Occupancy patterns (i.e. the total person hours spent at home and the person hours spent at home during the day)
- The number and efficiency of key appliances that are present, particularly air conditioners, heaters, refrigerators and home entertainment equipment
- The usage patterns for these appliances (i.e. time spent heating, cooling and using home entertainment equipment).

As peak demand is superimposed on average demand, the variables that are useful for predicting average demand are also useful for predicting peak demand. However, the number and efficiency of heating and cooling appliances and home entertainment equipment, and their usage patterns, appear to have the biggest impact on the size, shape and timing of peaks.

The descriptive case study analysis seemed to indicate that homes with air conditioners have the highest peak summer demand and homes that use a lot of electric heating have the highest peak winter demand. However, this influence did not emerge as strongly in the statistical analysis, with the exception of the strong influence of reverse cycle air conditioners on peak winter demand. Peaks can also result from the simultaneous use of home entertainment equipment, computers and cooking appliances in evening periods, even when heating and cooling does not take place.

The timing of peak demand varied across the sample. Although there was typically a morning peak and a higher evening peak, the timing depended on occupancy patterns. Further, use of heating or cooling appliances could create peaks outside of the typical times.

It would appear that there is definite scope to employ a similar methodology on other metering projects, using a larger sample to improve representation. It would be advantageous to design any future survey research in conjunction with the metering program, so that some of the methodological challenges faced during this study could be avoided. Future surveys could be designed to more closely target the variables identified as important during this study, providing a greater level of detail about occupancy patterns, heating and cooling, use of home entertainment equipment and other key factors that were not closely examined during this study, such as the influence of insulation on the timing and magnitude of peaks.

Finally, it is clear from this study that policies focused on the thermal efficiency of the building envelope and the efficiency of appliances installed at the time of construction only address one of the sources of variation in average and peak demand. Household behaviour, demographic characteristics, appliances installed by occupants and attitudes are other major sources of variation in average and peak demand that need to be considered in a comprehensive policy approach. In other words, technology alone will not bring about desired reductions in average and peak electricity demand. Attention to householder awareness and behaviour, through education, regulation and incentives, is also critical.

Appendix 1

Copy of package mailed out to each household

17 October 2005

NSW GOVERNMENT
Department of Planning

Demand Management and Planning Project

Chris Tully
Project Manager
Demand Management and Planning Project
Department of Planning
Suite 201, Level 2
52 Atchison St, St Leonards NSW 2065

Study of household electricity use in Newington

Dear Sir or Madam,

Over the past year, patterns of electricity use have been monitored in 30 Newington homes, including your home. This monitoring has been undertaken as part of the Demand Management and Planning Project (DMPP), which is a joint initiative of the NSW Department of Planning, TransGrid and EnergyAustralia. The main objective of the DMPP is to identify ways to avoid or defer costly public and private investment in new electrical infrastructure by developing accurate and reliable information on how to reduce consumer demand for electricity.

As the Project Manager for the DMPP, I am contacting you to ask for your assistance in another research project we are running in Newington over the next five weeks. The research will look at how your household characteristics affect your electricity use. The information collected will help us to develop ways to reduce the cost and environmental impact of providing electricity in Sydney.

I have asked the Institute for Sustainable Futures (ISF) at the University of Technology, Sydney to carry out this research. Enclosed with this letter, you will find a survey prepared by ISF. The survey lists three different ways you can take part in the research – by returning the survey by mail, completing the survey over the phone, or completing the survey in person. I would greatly appreciate it if you could take the time to participate in this research. ***All participants will receive a free energy efficient light bulb as a token of our appreciation.***

I hope that you are able to assist us with this important research project. If you would like any further information on the DMPP, please feel free to call me on (02) 9200 2203, email me on chris.tully@dipnr.nsw.gov.au or visit our website at www.iplan.nsw.gov.au/demandmgt/index.jsp.

If you would like any further information about the survey or general information about ISF, please feel free to call Dr Chris Riedy on (02) 9514 4964, email him on criedy@uts.edu.au or visit ISF's website at www.isf.uts.edu.au.

Yours sincerely,

Chris Tully
Project Manager
Demand Management and Planning Project

Study of household electricity use in Newington

Survey participation agreement

The Institute for Sustainable Futures (University of Technology, Sydney) (ISF) is undertaking a research project on household electricity use in Newington for the Demand Management and Planning Project (DMPP). ISF and the DMPP are committed to ethical research practices. This form explains what the research will involve and seeks your consent to take part in the research.

The purpose of the research is to improve understanding of household electricity use in Newington. We will collect information about your household (e.g. number of people, age, income etc) and how you use electricity (e.g. what appliances you have and when you use them). This information will help us understand the electricity meter readings that have already been collected from your home. The results will be used to find ways to reduce the cost and environmental impact of electricity supply.

Please note that all participants will remain anonymous – you will not be identified by name in any of the research reports or publications. The survey should only take about 20 minutes.

*******All participants will receive a free energy efficient light globe*******

*******These globes help you to save on energy bills and reduce environmental impacts*******

There are three ways you can choose to participate:

> **Option 1**: Complete the attached survey and mail it back to us using the enclosed, reply-paid envelope. You don't need a stamp. Make sure you include this form as well.

If you agree to participate in this research by completing the attached survey (Option 1), please complete the following and return it with your survey:

Name:	
Address:	
Signature:	
Date:	
Telephone: (optional)[1]	

(Please turn over)

[1] If you provide a telephone number, we will be able to contact you if we need to clarify anything you have written in the survey.

Option 2: Call Dr Chris Riedy at the Institute for Sustainable Futures and complete the survey over the phone.

If you agree to participate in this research by completing the survey over the phone (Option 2), please call Dr Chris Riedy on 9514 4964. Chris will seek your consent to participate in the research over the phone.

Option 3: Participate in an interview in your home to complete the survey. Dr Chris Riedy and Emma Partridge from the Institute for Sustainable Futures will visit Newington several times during November to conduct interviews.

If you agree to participate in an interview in your home (Option 3), please call Dr Chris Riedy on 9514 4964. Chris will arrange a suitable time to visit.

If you do not wish to participate in the research in any way, please complete the following and return this form in the enclosed, reply-paid envelope. You will not be contacted again.

The occupants of the home at the following address would prefer not to participate in this research project.

Address:	
Reason for not participating:	

If you have any questions or concerns about the research, please contact Dr Chris Riedy from ISF on (02) 9514 4964.

Note: Studies undertaken by the Institute for Sustainable Futures have been approved in principle by the University of Technology, Sydney, Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research, you may contact Ms Ann Hobson, the Research and Publications Coordinator at ISF, [tel 02 9514 4974] or the UTS Ethics Committee through the Research Ethics Officer, Ms Susanna Davis [tel: 02 9514 1279]. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Survey: Household electricity use in Newington

Please complete each of the questions below by writing your answer or placing an ☒ in the appropriate box. If you do not wish to answer some of the questions, leave those questions blank.

The survey has four parts and should take about 20 minutes to complete.

Part 1: About your household

1. How many people live in your home?

Write your answer here:

2. Which of the following best describes the people living in your household?

A single adult	
Two adults with no children under 18	
A single adult with children under 18	
Two adults with children under 18	
More than two adults with no children under 18	
More than two adults with children under 18	

3. For each person living in your household, please complete the following table.

Person #:	**1**	**2**	**3**	**4**	**5**	**6**
Age						
Male or female						

4. How many bedrooms are there in your home?

Write your answer here:

5. What is the estimated weekly income of your household (after tax)?

Less than $200	
$200-$399	
$400-$599	
$600-$799	
$800-$999	
$1,000-$1,199	
$1,200-$1,399	
$1,400 and above	

6. Which of the following best describes your house?

Owned or part-owned by you	
Rented or part-rented by you	
Other	

7. Do any of your household members have a disability?

Yes	
No	

8. Does anyone in the household speak a language other than English at home?

Yes	
No	

institute for sustainable futures

UNIVERSITY OF TECHNOLOGY SYDNEY

Part 2: Your energy use

1. What is the name of your electricity supplier?

Write your answer here:

2. How often do you receive your electricity bill?

Weekly	
Fortnightly	
Monthly	
Quarterly	
Every six months	
Once a year	
Other	

*3. How many adults and children (under 18) are **usually** at home in the morning (before 9am) on the following days?*

Day:	**Mon**	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**
Adults (over 18)							
Children (under 18)							

*4. How many adults and children are **usually** at home during the day (between 9am and 3pm) on the following days?*

Day:	**Mon**	**Tue**	**Wed**	**Thur**	**Fri**	**Sat**	**Sun**
Adults (over 18)							
Children (under 18)							

*5. How many adults and children are **usually** at home in the afternoon (between 3pm and 6pm) on the following days?*

Day:	Mon	Tue	Wed	Thur	Fri	Sat	Sun
Adults (over 18)							
Children (under 18)							

*6. How many adults and children are **usually** at home during the evening (after 6pm) on the following days?*

Day:	Mon	Tue	Wed	Thur	Fri	Sat	Sun
Adults (over 18)							
Children (under 18)							

7. Are you aware of any alterations to the original design of your house? Alterations might include renovations, extensions, replacement of original appliances, or installation of a new heater, air conditioner or water heater.

Yes	
No	

If yes, please provide any information you can on when the alteration was made and what was changed.

Part 3: Your appliances

This section of the survey asks questions about the main appliances used in each room in your house and the way they are used.

<u>3a. Lighting</u>

1. Please complete the following table indicating how many of each type of light bulb you have in your home (in total).

Appliance		**How many of these do you have?**
Standard light bulb (include any lamps)		
Halogen light bulb (down or spot light)		
Energy efficient light bulb		
Tubular fluorescent light		
Heat lamp		

2. Do you leave any external lights on at night for security?

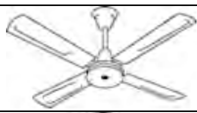
Yes	
No	

3b. Heating and cooling

1. Please complete the following table indicating how many of each type of electric heater you have in your home (if any).

Appliance	How many of these do you have?
Radiant heater 	
Fan heater 	
Oil column heater 	
Convection heater 	

2. Please complete the following table indicating how many of each type of fan or air conditioner you have in your home (if any).

Appliance	How many of these do you have?
Ceiling fan 	
Portable fan 	
Air conditioner 	
Evaporative cooler 	

3. If you have an electric heater, fan or air conditioner, please write down the time of day that your household typically uses it (e.g. from 6am to 8am in the morning, from 4pm to 7pm in the evening, all day in winter, etc).

Appliance	**When do you use it?**
Electric heater	
Fan	
Air conditioner	

4. If you have an electric heater, please write down when you would turn it on and when you would turn it off ***on a very cold day in winter****.*

We would turn the heater on at…	***We would turn the heater off at…***

5. If you have and air conditioner or fan, please write down when you would turn it on and when you would turn it off ***on a very hot day in summer****.*

We would turn the air conditioner on at…	***We would turn the air conditioner off at…***

6. If you have an air conditioner, please indicate below what type it is.

Portable	
Refrigerative (wall or window mounted)	
Reverse cycle	
Ducted	

3c. White goods

1. Please complete the following table indicating how many of each type of white good you have in your home. Add the size of your fridges if you know it.

Appliance	How many of these do you have?	Size (litres)
Refrigerator (without freezer)		
Refrigerator (with freezer)		
Separate freezer		
Dishwasher		
Washing machine		
Clothes dryer		

2. For the following white goods, please write down the time of day when your household typically uses it (e.g. 7am in the morning, 7pm in the evening, etc).

Appliance	When do you use it?
Dishwasher	
Washing machine	
Clothes dryer	

3. Please complete the following table for each appliance that you have.

Appliance	Loads per week
Dishwasher	
Washing machine	
Clothes dryer	

3d. Home entertainment and home office

1. Please complete the following table indicating how many of each type of home entertainment and/or home office appliance you have in your home.

Appliance	**How many of these do you have?**
Television (standard)	
Television (large flat screen)	
Television (large plasma screen)	
DVD player	
Video cassette recorder	
Stereo system	
Home theatre system	
Computer	

2. Please write down the time of day when your household typically uses home entertainment and home office equipment (e.g. 6am – 7am in the morning, 6pm – 10 pm in the evening, weekend mornings, etc)?

Appliance	**When do you use it?**
Home entertainment (TVs, DVDs, VCRs, stereos and home theatres)	
Computer	

3e. Other appliances and equipment

1. Please complete the following table indicating how many of each appliance you have in your home.

Appliance	**How many of these do you have?**
Exhaust fan (bathrooms)	
Hair dryer	
Waterbed	
Exhaust fan/rangehood (kitchen)	
Microwave oven	
Small kitchen appliances (e.g. kettle, toaster, blender, juicer, electric frypan)	
Vacuum cleaner	
Iron	

2. Please write down the time of day when your household typically uses the following appliances (e.g. 6am – 7am in the morning, 6pm – 10 pm in the evening, weekend mornings, very rarely, etc)?

Appliance	**When do you use it?**
Hair dryer	
Microwave oven	
Electric oven	
Vacuum cleaner	
Iron	

3f. General timing questions

1. At what times of day does your household use the bathrooms the most on a weekday? Please mark the times of heaviest use. You can mark more than one time.

Midnight - 5am		4pm - 5pm	
5am - 6am		5pm - 6pm	
6am - 7am		6pm - 7pm	
7am - 8am		7pm - 8pm	
8am - 9am		8pm - 9pm	
9am - 10am		9pm - 10pm	
10am - 3pm		10pm - 11pm	
3pm - 4pm		11pm - midnight	

2. At what time in the morning does the first member of your household usually get up on a weekday?

3. At what time in the evening does the last member of your household usually go to bed on a weekday?

4. Do any members of the household do shift work that requires them to work at night and sleep during the day?

5. Please estimate how many times your household prepare meals at home each week?

Breakfast	Lunch	Dinner

6. At what times of day does your household use your kitchen the most on a weekday? Please mark the times of heaviest use. You can mark more than one time.

Midnight - 5am		4pm - 5pm	
5am - 6am		5pm - 6pm	
6am - 7am		6pm - 7pm	
7am - 8am		7pm - 8pm	
8am - 9am		8pm - 9pm	
9am - 10am		9pm - 10pm	
10am - 3pm		10pm - 11pm	
3pm - 4pm		11pm - midnight	

7. At what times of day does your main living area get used the most on a weekday? Please mark the times of heaviest use. You can mark more than one time.

Midnight - 5am		4pm - 5pm	
5am - 6am		5pm - 6pm	
6am - 7am		6pm - 7pm	
7am - 8am		7pm - 8pm	
8am - 9am		8pm - 9pm	
9am - 10am		9pm - 10pm	
10am - 3pm		10pm - 11pm	
3pm - 4pm		11pm - midnight	

Part 4: Your knowledge and opinions

1. Please complete the following table by marking the box that best represents your personal opinion about each statement.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have received information about saving energy in the past					
I have sought information about saving energy in the past					
I am actively involved in groups that promote environmental issues					
I actively try to save energy around the house					
I always turn off lights when they are not being used					
I am concerned about the size of my electricity bill					
I am concerned about the environmental impact of my electricity use					
I am concerned about climate change					
I am aware that there is a solar panel on our roof					

2. There is a solar photovoltaic (PV) panel installed on your roof. Please answer the following questions about this solar panel.

Question	**Yes**	**No**
Do you understand how your solar PV panel works?		
Are you aware that the solar PV panel exports electricity to the grid as well as supplying your house?		
Would you know if the solar PV panel stopped working?		

3. When your house was built, there was a gas-boosted solar water heater installed on your roof. Please answer the following question about this solar water heater.

Question	**Yes**	**No**
Is the solar water heater still there?		
Has the solar water heater been replaced with an electric water heater?		
If the solar water heater is still there, would you know if it stopped working?		

Appendix 2

Copy of reminder letter left with non-responding households

24 November 2005

Study of household electricity use in Newington

Dear Sir or Madam,

Over the past year, the Demand Management and Planning Project (DMPP) has measured the amount of electricity used by your home as part of a research project on solar power. The DMPP will use the results to develop ways to reduce the cost and environmental impact of providing electricity in Sydney. Thirty homes in Newington are participating in the study.

The Institute for Sustainable Futures is now collecting information from residents of these 30 homes to help us to understand patterns of electricity use. We need some basic information on your household characteristics and appliances to help us to understand the data recorded over the last year.

Recently, you would have received a survey in the mail with questions about your household characteristics and electricity use. We are now visiting those homes that have not yet had a chance to return the completed survey to us. We visited your house today but you were not home.

If you still have a copy of the survey, we would greatly appreciate it if you could complete it and return it to us, using the self-addressed envelope, by **Wednesday 30th November**. If you no longer have a copy of the survey, please contact Dr Chris Riedy and we can either send you out another copy or complete it over the phone with you. We have attached a business card with Chris' contact details (telephone, fax and email).

If you would prefer to complete the survey in person, we will be visiting Newington again early next week. Please feel free to contact Dr Chris Riedy to arrange a suitable time for a visit. The survey should take less than half an hour to complete.

Remember, all participating households will receive a FREE pack of energy saving light bulbs as a token of our appreciation.

I hope that you are able to assist us with this important research project. If you would like any further information about this project, please contact Dr Chris Riedy (see attached business card).

Yours sincerely,

Chris Riedy
Research Principal
Institute for Sustainable Futures

Emma Partridge
Research Principal
Institute for Sustainable Futures

Appendix 3

Copy of letter offering additional incentive

2 December 2005

Study of household electricity use in Newington

Dear Sir or Madam,

Over the past year, the Demand Management and Planning Project (DMPP) has measured the amount of electricity used by your home as part of a research project on solar power. The DMPP will use the results to develop ways to reduce the cost and environmental impact of providing electricity in Sydney. Thirty homes in Newington are participating in the study.

The Institute for Sustainable Futures is now collecting information from residents of these 30 homes to help us to understand patterns of electricity use. We need some basic information on your household characteristics and appliances to help us to understand the data recorded over the last year.

Recently, you would have received a survey in the mail with questions about your household characteristics and electricity use. Your response is very important to the success of our research, so I would like to offer you a final incentive to complete and return the survey.

If you complete and return the survey by ***Wednesday 14th December 2005***, we will send you a $50 WISH Gift Card from Woolworths. The card will allow you to spend $50 however you like at participating stores (including Woolworths at Newington Marketplace and many other stores).

More information on the WISH Gift Card is available from www.wishgiftcard.com.au

To receive your free $50 WISH Gift Card, all you need to do is complete the enclosed survey and mail it back to us in the enclosed, reply-paid envelope. You don't need a stamp. If we receive your completed survey by ***Wednesday 14th December 2005***, we will mail you your WISH Gift Card.

I hope that you are able to assist us with this important research project. If you would like any further information about this project, please contact Dr Chris Riedy on (02) 9514 4964 or criedy@uts.edu.au.

Yours sincerely,

Chris Riedy
Research Principal
Institute for Sustainable Futures

Level 11, UTS Building 10, 235 Jones Street, Ultimo, 2007
Mailing Address: UTS, PO Box 123, Broadway, Sydney, NSW 2007
Tel: 61 2 9514 4950 Fax: 61 2 9514 4941 E-mail: isf@uts.edu.au Web: www.isf.uts.edu.au

Appendix 4
Data analysis details

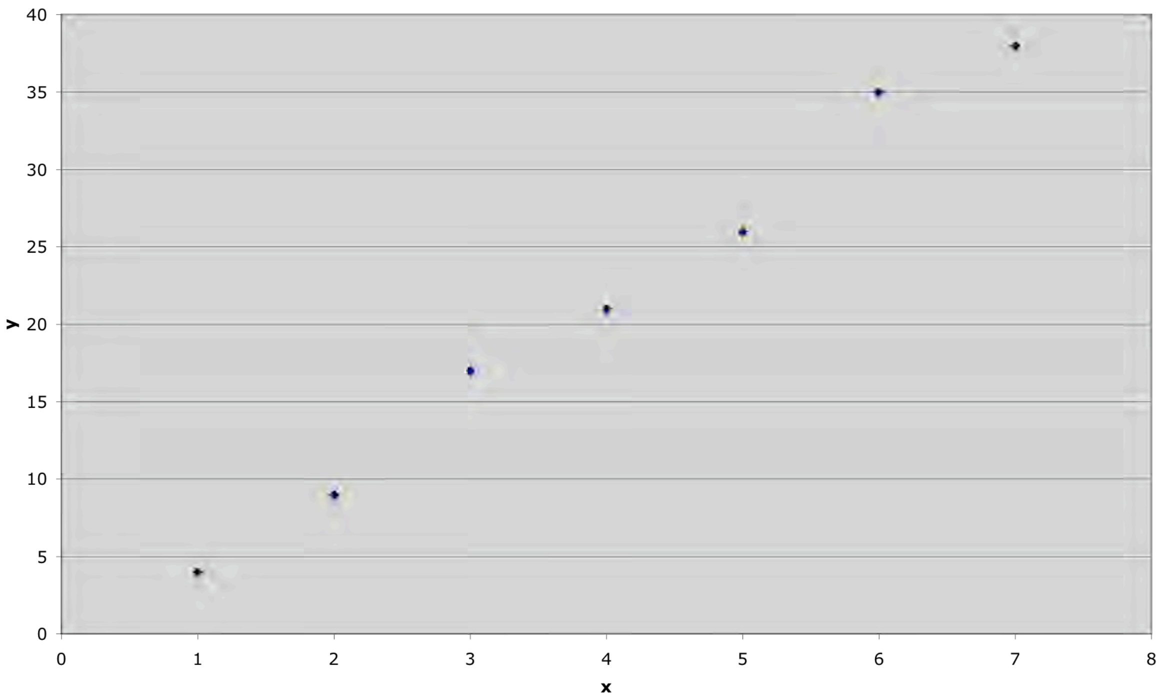
This Appendix provides additional details on the data analysis techniques used during the study for those with a particular interest in the methodology.

Linear regression

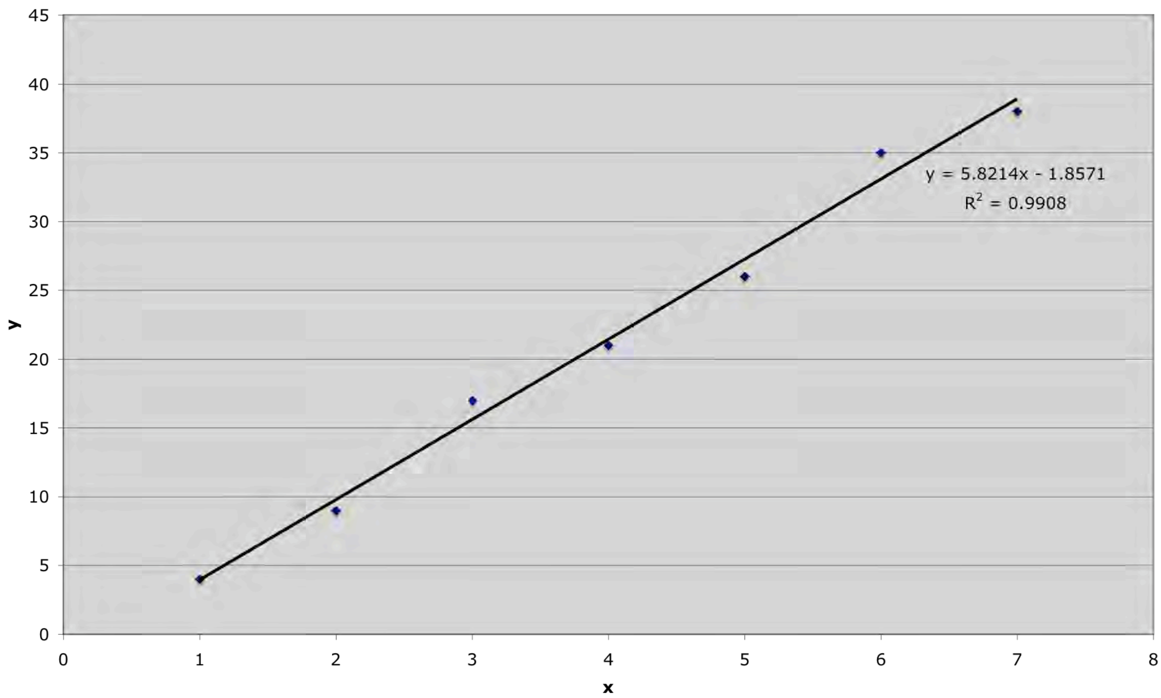
As noted in Section 2.4.2, linear regression is a technique that identifies a linear relationship between two sets of variables. Consider the variables, x and y in the table below.

Site Number	y	x
1	4	1
2	9	2
3	17	3
4	21	4
5	26	5
6	35	6
7	38	7

When plotted on a chart (below), it is apparent to the naked eye that we can draw a straight line that will be a close match to the pattern on the chart.



Linear regression is a mathematical technique that identifies the line that provides the best possible fit to the data in the chart. It gives the equation for the line in the form $y = mx + b$, where x and y are the variables plotted above, m is the slope of the line (the amount that y increases when x increases by 1) and b is the point at which the line meets the y-axis. For the example above, the line that best fits the data is given by the equation $y = 5.8214x – 1.8571$. This line, and its equation, are shown on the graph below. In this case, $m = 5.8214$, which means that y increases by 5.8214 when x increases by 1. The line would meet the y-axis at -1.8571, as $b = -1.8571$.



The chart above also gives an indication of how well the straight line fits the available data by showing the R^2 value. The R^2 value indicates how much of the variation in the raw data is captured by the straight line. In this case, $R^2 = 0.9908$, so 99.08% of the variation is captured by the straight line. This is an extremely close fit.

Multiple linear regression

Multiple linear regression is a more complex version of linear regression. Instead of explaining the variation in *y* using a single x-variable, it uses multiple x-variables, as shown in the table below.

Site Number	y	x_1	x_2	x_3	x_4
1	0.140	1	3	1	4
4	0.473	4	5	5	3
6	0.149	2	5		3
8	0.348	1	4	2	3
10	0.157	3	4	1	3
11	0.339	3	4	1	3
14	0.164	4	4		4

Multiple linear regression tries to identify a straight line that fits the available data, using all the available x-variables. In this case, the line would have the following equation:

$$y = b + m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4$$

The software used to run the multiple regression gives b and m_1 to m_4. It also gives the R^2 value, which has the same meaning as described above for linear regression. In a real situation, there can be many more than four x-variables.

The sections below outline how multiple linear regression was applied during this study.

Metering variables (the y-variables for this study)

First, a set of metering variables was developed to capture the main varying features across the 30 load profiles. The metering variables were calculated separately for the March and June datasets, and included:

- Average half-hourly demand
- Peak (maximum) demand for the week
- Minimum demand for the week
- The demand range (difference between the peak demand and the minimum demand)
- The ratio of the peak demand to the average demand
- The number of half-hourly intervals in which demand was more than double average demand
- The number of half-hourly intervals in which demand was more than four times average demand.

The first two variables (average half-hourly demand and peak demand) were used as y-variables for the multiple regression analysis.

Survey variables (the x-variables for this study)

Second, the fifteen survey responses were collated and a set of summary variables was developed to capture the variation in the survey data. The following variables were developed for each respondent household (the names in bold are identifiers used throughout the report):

- **Household size** (i.e. number of persons living in the home)
- Number of **children under 18**
- Number of **bedrooms** in the home
- Weekly household **income** (after tax)[16]
- A dummy variable identifying households where any of the residents speak a language other than English at home (one for yes, zero for no) (**NESB**)
- The number of energy bills received each year (**bills**)
- The number of incandescent and halogen lights (**high-watt lights**)
- The number of fluorescent tubes and compact fluorescent lights (**low-watt lights**)
- The number of **heaters**

[16] The survey categories for household income gave income ranges. The median income from each income range was used to assign a numeric value to survey responses.

- The number of **fans** (both ceiling and portable)
- The number of air conditioners (**air con**)
- The number of reverse cycle air conditioners (**RC air con**)
- A dummy variable identifying the presence of an air conditioner (**air con presence**)
- The number of refrigerators (**fridges**)
- The number of **dryers**
- The total number of **appliances and fixtures** (including lights and small appliances)
- The number of person hours spent at home between 9am and 6pm (**hours home (day)**)
- The total number of person hours spent at home (**hours home**)
- The number of **meals** prepared at home
- Eight variables representing the degree of agreement with the following statements:
    - I have received information about saving energy in the past (**received info**)
    - I have sought information about saving energy in the past (**sought info**)
    - I am actively involved in groups that promote environmental issues (**enviro active**)
    - I actively try to save energy around the house (**energy saver**)
    - I always turn off lights when they are not being used (**lights off**)
    - I am concerned about the size of my electricity bill (**bill concern**)
    - I am concerned about the environmental impact of my electricity use (**env concern**)
    - I am concerned about climate change (**CC concern**)
- Hours per day that fans are used on a hot day (**fan time**)
- Hours per day that air conditioners are used on a hot day (**air con time**)
- Hours per day that heaters are used on a cold day (**heater time**).

In each multiple regression, we used a subset of the above variables as the x-variables. That is, we tried to identify which of the survey variables best explained the variation in the metering variables (average demand and peak demand). Separate analyses were undertaken for March and June data.

Multiple regression methods

This section provides more detail on the multiple regression methods that we used for our analysis. We used two separate methods to identify which of the survey variables were the most useful for predicting the observed variation in the metering variables.

First, we used a method called **best subsets regression**. This method has the following steps:

1. Choose one of the metering variables, e.g. peak demand in March.

2. Examine the list of survey variables and choose the variables that seem most likely to explain the variation in peak demand in March. For mathematical reasons, we could only choose up to 14 survey variables for this procedure. A possible list is:

    a. Household size

    b. The number of high-watt lights

    c. The number of fans

    d. The number of air conditioners

    e. The number of reverse-cycle air conditioners

    f. The presence of an air conditioner

    g. The number of dryers

    h. The number of person hours spent at home during the day

    i. The hours per day that fans are used on a hot day

    j. The hours per day that air conditioners are used on a hot day.

3. Use a statistical program (e.g. Minitab) to do best subsets regression. Minitab runs through all the possible combinations of the survey variables above and identifies a linear equation that uses the survey variables to explain the peak demand in March. It also gives the R^2 value for each combination of variables. For example:

    a. The number of fans alone explains 32% of the variation in peak demand in March

    b. The number of fans plus the presence of an air conditioner explains 36% of the variation

    c. The number of fans plus the number of air conditioners plus the presence of an air conditioner plus the hours per day that air conditioners are used on a hot day explains 42% of the variation

4. Examine the Minitab output to identify the combination of survey variables that explains the highest proportion of the variation in average peak demand in March. These variables are used as the input to the next regression method.

The second regression method we used is called **stepwise regression**. This method has the following steps:

1. In a statistical program such as Minitab, the best combination of survey variables identified above is defined as an initial regression model for stepwise regression.

2. Select other survey variables that were not considered during the best subsets regression, e.g. the number of fridges.

3. Use Minitab to run a stepwise regression. Minitab starts with the initial regression model and progressively adds and removes other survey variables in an attempt to find a better regression model. Minitab adds or removes a survey variable if there is less than a 10% chance that the relationship between that survey variable and the metering variable is due to random chance.

4. Run the stepwise regression several times to test different combinations of survey variables. Each time, Minitab provides a list of the final set of variables in the regression model and the R^2 value.

5. Choose the model with the highest R^2 value and examine the regression model to see if it makes logical sense. For example, it is not logical for the peak demand in March to decrease as the number of air conditioners in the home increases. If the regression model predicts this, it may need to be modified.

6. Exclude any survey variables that do not give logical results and run the stepwise regression again.

7. Repeat the process until a final regression model is identified that is logically defensible and has the highest R^2 value. For example, for peak demand in March, the following variables were included in the final regression model, which had $R^2 = 98.9\%$:

    a. The number of:

        i. Fridges

        ii. Reverse cycle air conditioners

        iii. High-watt lights

        iv. Fans

    b. Agreement with the statements:

        i. I have received information about saving energy in the past (**received info**)

        ii. I actively try to save energy around the house (**energy saver**)

    c. The number of person hours spent at home during the day.

Appendix 5
Summary of Metering Variables

Site	Metering Variables													
	Average Demand (Mar)	Average Demand (June)	Peak Demand (Mar)	Peak Demand (June)	Min Demand (Mar)	Min Demand (June)	Range (Mar)	Range (June)	# of 2x Peaks (Mar)	# of 2x Peaks (June)	# of 4x Peaks (Mar)	# of 4x Peaks (June)	Peak/Ave (Mar)	Peak/Ave (June)
	(kW)													
1	0.140	0.160	0.351	1.248	0.068	0.093	0.283	1.155	2.0	10.0	0.0	3.0	2.5	7.8
4	0.473	0.765	1.901	3.479	0.139	0.189	1.762	3.290	39.0	31.0	1.0	1.0	4.0	4.5
6	0.149	0.836	0.806	2.935	0.044	0.022	0.762	2.913	47.0	73.0	4.0	0.0	5.4	3.5
8	0.348	0.433	2.319	2.068	0.062	0.059	2.257	2.009	37.0	58.0	18.0	22.0	6.7	4.8
10	0.157	0.177	1.099	1.197	0.040	0.031	1.059	1.166	38.0	57.0	9.0	15.0	7.0	6.8
11	0.339	0.789	1.655	2.130	0.108	0.104	1.547	2.026	17.0	16.0	4.0	0.0	4.9	2.7
14	0.164	0.165	0.543	0.790	0.042	0.036	0.501	0.754	43.0	50.0	0.0	2.0	3.3	4.8
17	0.385	0.335	3.589	1.381	0.111	0.147	3.478	1.234	29.0	22.0	14.0	1.0	9.3	4.1
18	0.498	0.425	2.956	3.337	0.150	0.116	2.806	3.221	31.0	29.0	23.0	22.0	5.9	7.9
19	0.348	0.283	1.450	1.053	0.110	0.109	1.340	0.944	26.0	23.0	1.0	0.0	4.2	3.7
20	0.225	0.309	1.435	2.346	0.059	0.051	1.376	2.295	27.0	40.0	9.0	21.0	6.4	7.6
21	0.248	0.622	1.104	1.885	0.083	0.079	1.021	1.806	33.0	38.0	1.0	0.0	4.5	3.0
24	0.340	0.233	1.207	1.679	0.140	0.005	1.067	1.674	12.0	52.0	0.0	6.0	3.5	7.2
25	0.119	0.236	1.299	2.291	0.042	0.046	1.257	2.245	18.0	45.0	5.0	20.0	10.9	9.7
26	0.410	0.069	1.519	0.277	0.099	0.004	1.420	0.273	23.0	5.0	0.0	1.0	3.7	4.0
Average	**0.290**	**0.389**	**1.549**	**1.873**	**0.087**	**0.073**	**1.462**	**1.800**	**28.133**	**36.600**	**5.933**	**7.600**	**5.479**	**5.479**

Appendix 6
Summary of Survey Responses

6A: Demographic responses (Part 1)

Site	Household Size	Household Structure[17]	Age 1	Age 2	Age 3	Age 4	Children under 18	Gender 1	Gender 2	Gender 3	Gender 4	Bedrooms	Weekly Income[18]	Ownership
1	1	1	35				0	M				4	6	1
4	4	4	33	30	2	10 mths	2	M	F	M	M	3	5	3
6	2	2	59	56			0	M	F			3	8	1
8	1	1	40				0	F				3	NR[19]	1
10	3	4	42	38	8		1	M	F	M		3	8	1
11	3	5	55	53	22		0	M	F	M		3	8	2
14	4	6	53	51	50	15	1	F	F	M	M	4	7	1
17	2	2	38	43			0	M	F			3	8	1
18	2	2	67	65			0	M	F			4	8	1
19	4	5	23	20	47	42	0	M	M	M	f	3	4	3
20	2	2	29	23			0	M	F			3	7	3
21	3	4	34	32	5		1	M	F	M		3	7	1
24	2	2	27	31			0	M	F			3	8	1
25	2	2	35	30			0	M	F			3	8	1
26	3	5	32	24	18		0	M	F	F		3	8	1

[17] 1 = a single adult, 2 = 2 adults, no kids, 3 = Single parent family, 4 = Two parent family, 5 = More than 2 adults, no kids, 6 = More than two adults, with kids.

[18] 1 = <$200, 2 = $200-$399, 3 = $400-$599, 4 = $600-$799, 5 = $800-$999, 6 = $1000-$1199, 7 = $1200-$1399, 8 = $1400 and above.

[19] NR = no response given.

6B. Demographic responses (Part 2)

Site	Disability	NESB	Supplier	Bills per year	Alterations
1	N	Y	EA	4	N
4	N	Y	EA	4	Y
6	N	N	EA	4	N
8	N	N	AGL	4	Y
10	N	Y	EA	4	N
11	N	N	EA	4	N
14	N	Y	EA	4	N
17	N	Y	AGL	4	Y
18	N	N	NR	4	N
19	N	Y	AGL	4	N
20	N	N	EA	4	Y
21	N	Y	Sydney Electricity	12	N
24	N	Y	Sydney Electricity	4	N
25	N	N	EA	4	N
26	N	Y	AGL	4	NR

6C. Appliances (Part 1)

Site	Number of light fittings						Number of electric heaters				Number of cooling appliances			
	Incandescents	Halogens	CFLs	Fluoro tube	Heat lamp	Outdoor night light	Radiant	Fan	Oil	Convection	Ceiling	Portable	Air con	Evap cooler
1	0	3	19	3		N	1					2	1	
4	14	15	3	9	1	N	0	1	3	0	0	1	5	0
6	16	3	2			N		1	3			1		
8	12	3	4	1		N							2	
10	16	8	4	5		N			2			3	1	
11	11	4		6		N			3			3	1	
14	31	6		1		N		1	2			5		
17	9	24	10	1		N							1	
18	10	2		1		N							1	2
19	3	2				N						2	2	
20	16	5	1			N		1				3	1	
21	20		3			Y	2		1			1		1
24	18	10	2			N			1			1		
25	2	2	17	3		N		2			3	1		1
26	4	16	25			N						3		

6D. Appliances (Part 2)

Site	Kitchen				Laundry		Weekly loads		
	Fridge	Fridge/Freezer	Freezer	Dishwasher	Washing machine	Clothes Dryer	Dishwasher	Washing machine	Dryer
1		1		1	1		2	2	
4	0	1	0	1	1	0	4	4	
6		1		1	1	1	7	2	
8		1		1	1	1	2	2	0
10		1		1	1		1.5	9	
11		1		1	1	1	1	8	1
14		1		1	1			3	
17	2	1		1	1		4	4	
18		2		1	1	1	2	5	Seldom
19		1		1					
20		2		1	1		7	3	
21		1		1	1		2	2	
24		1	1	1	1	1	2	1	0.5
25		1		1	1	1	1	3	2
26		1		1	1		7	10	

6E. Appliances (Part 3)

Site	Home entertainment and office								Other appliances							
	TV	TV (flat screen)	TV (plasma)	DVD	VCR	Stereo	Home theatre	Computer	Exhaust fan	Hair dryer	Water bed	Range hood	Microwave	Small kitchen	Vacuum	Iron
1	1			1	1	1		2	2			1	1	1	1	1
4	2	0	1	2	2	2	1	2	3	1	0	1	1	5	1	1
6	1			1		1		1	3	1		1	1	2	1	1
8	2			1	2	1		1	2	1		1	1	6	1	1
10	1	1		1	1	1	1	1		1		1		6	1	1
11	2			1	2	1		2	1	1		1	1	3	1	1
14	1			2	1	1		2	3	2		1	1	3	1	1
17	3			1	1	1		1		1	1	1	1	8	1	1
18	2	1		1	1	1		1	2	1		1	1	4	1	1
19	2			1	1	1		2		1			1	2	1	1
20	1				1	2		4	2	1		1	1	4	1	1
21	1	1		1	1	1		1	1	1			1		1	1
24	2			1	1	1		1	4	1		1	1	4	1	1
25	3			1	1		1	1	1	1		1	1	1	1	1
26		1	1	1		1	1	2		1		1	1	2	1	1

6F. Behaviour

Site	Morning wake up time	Evening bed time	Shift work	Weekly meals at home			Hours per day using…		
				Breakfast	Lunch	Dinner	Fan on a hot day	Air con on a hot day	Electric heater on a cold day
1	7	11	N	6	2	4	3	4	0
4	6.30	11.30	N	7	4	7	13	9	9
6	6	10.30	N	7	2	6	0	0	4
8	6	10.30	N	7	2	5	0	4	4
10	5.20	10.30	N	12	3	7	9	5	5
11	6.30	12	N	7	4	7	16	12	13
14	6	10.30	N	7	5	6	7	0	0
17	5.30	10	N	7	5	5	0	11	0
18	6.30	10	N	7	6	6	0	0	0
19	7.30	2	N	0	0	5	0	0	0
20	6.30	11	N	7	2	6	2	8	4
21	7	11	N	7	4	7	20	0	22
24	6.45	11.30	N		1	3	3	0	0
25	6.15	10	N	7		7	3	0	0
26	6	11	N		5	7	11	0	0

6G. Attitudes, opinions and awareness (Part 1)[20]

Site	Received information about saving energy	Sought information about saving energy	Actively involved in environmental groups	Actively try to save energy	Always turn lights off when not in use	Concerned about the size of my bill	Concerned about env impact of electricity	Concerned about climate change	Aware that there is a solar panel on our roof
1	3	3	2	3	4	3	3	3	4
4	5	4	3	5	5	4	4	4	5
6	5	4	3	4	4	4	4	4	5
8	4	3	2	4	4	2	3	3	4
10	4	1	1	4	5	4	5	4	5
11	4	4	1	5	5	5	4	5	5
14	4	2	1	3	4	3	3	4	5
17	1	1	1	5	5	2	1	3	5
18	3	1	1	5	5	5	5	5	5
19	2	2	2	4	4	4	4	4	4
20	4	4	2	4	4	3	4	4	4
21	3	2	1	3	5	4	4	4	4
24	4	3	3	4	4	2	4	3	4
25	4	4	4	5	5	3	4	4	5
26	2	4	2	4	3	5	4	4	4

[20] 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

6H. Attitudes, opinions and awareness (Part 2)

Site	Understand how your PV panel works?	Aware that PV panel exports to grid as well as supplying house?	Would you know if PV panel stopped working?	Is the SWH still there?	Has the SWH been replaced with electric?	Would you know if SWH stopped working?
1	Y	Y	Y	Y	N	Y
4	Y	Y	N	Y	N	Y
6	Y	Y	Y	Y	N	Y
8	Y	Y	Y	Y	N	Y
10	Y	Y	N	Y	N	Y
11	Y	Y	Y	Y	N	Y
14	Y	Y	N	N	N	N
17	Y	Y	Y	Y	N	Y
18	N	Y	Y	Don’t know	NR	N
19	Y	Y	Y	Y	Y	Y
20	N	N	N	Y	N	N
21	Y	Y	N	Y	N	N
24	N	N	N	Y	N	Y
25	Y	Y	N	Y	N	Y
26	N	N	N	Y	N	N